PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXX.

JANUARY TO DECEMBER, 1904.

NEW YORK:

PUBLISHED BY THE SOCIETY.

1904.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

INDEX.

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

January, 1904.

PROCEEDINGS - VOL. XXX—No.

Published at the House of the Society, 220 West Fifty-seventh Street, New Y
the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15th

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXX. No. 1.

JANUARY, 1904.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1904.

American Society of Civil Engineers.

OFFICERS FOR 1904.

President, CHARLES HERMANY.

Vice-Presidents.

Term expires January, 1905:
L. F. G. BOUSCAREN,
JAMES D. SCHUYLER.

Term expires January, 1906:
F. S. CURTIS,
S. L. F. DEYO.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1905:	*Term expires January, 1906:*	*Term expires January, 1907:*
RICHARD S. BUCK,	ALFRED CRAVEN,	CHARLES S. GOWEN,
GEORGE H. PEGRAM,	JOSEPH O. OSGOOD,	N. P. LEWIS,
WILLIAM J. WILGUS,	GEORGE S. DAVISON	JOHN W. ELLIS,
WILLIAM JACKSON,	E. C. LEWIS,	GEORGE S. WEBSTER,
EDMUND F. VAN HOESEN,	HUNTER McDONALD.	RALPH MODJESKI,
JAMES L. FRAZIER.	ELWOOD MEAD.	CHARLES D. MARX.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
S. L. F. DEYO,	GEORGE H. PEGRAM,	N. P. LEWIS,
L. F. G. BOUSCAREN,	ALFRED CRAVEN,	WILLIAM JACKSON,
RICHARD S. BUCK,	JOSEPH O. OSGOOD,	E. C. LEWIS,
WILLIAM J. WILGUS.	GEORGE S. DAVISON.	RALPH MODJESKI,
CHARLES S. GOWEN,	HUNTER McDONALD.	CHARLES WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

ON RAIL SECTIONS:—G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 588 Columbus.
CABLE ADDRESS, - - - - - "Ceas, New York."

Vol. XXX. JANUARY, 1904. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

January 6th, 1904.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Charles Warren Hunt, Secretary; and present, also, 103 members and 10 guests.

The minutes of the meetings of December 2d and 16th, 1903, were approved as printed in the *Proceedings* for December, 1903.

A paper, entitled "Theory of the Spherical Dome with a Homogeneous Surface, and of the Framed Dome; Also Notes on the Construction of Masonry and Metal Domes," by E. Schmitt, Assoc. M. Am. Soc. C. E., was presented by the author and illustrated with

lantern slides. A communication on the paper, from Irving P. Church, Assoc. Am. Soc. C. E., was presented by the Secretary.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Richard Parkhurst Bloss, Mechanicsville, N. Y.
James Francis Case, Manila, Philippine Islands.
Henry Frederick Dose, New York City.
Harrison Souder, Johnstown, Pa.

As Associate Members.

Frederick Whitney Adgate, Omaha, Nebr.
Harold Kilbreth Barrows, Burlington, Vt.
Herbert Nichols Cole, Milwaukee, Wis.
Noah Cummings, New York City.
Andrew Daniel Fuller, Boston, Mass.
John Roworth Rainbow, New York City.
Eugene Peronneau Roundey, Utica, N. Y.
Eddy Elbert Young, New York City.

As Associate.

Safford Kinkead Colby, New York City.

The Secretary announced the transfer of the following candidates, by the Board of Direction, on January 5th, 1904, from the grade of Associate Member to the grade of Member:

As Members.

Edwin James Beugler, Boston, Mass.
Ernest Henry Brownell, Portsmouth, N. H.
James Burden, Troy, N. Y.
Leonard Martin Cox, Sparrows Point, Md.
Frederic Harold Fay, Boston, Mass.
Clarence William Hubbell, Detroit, Mich.
Julian de Bruyn Kops, Savannah, Ga.
Charles Adriance Mead, Upper Montclair, N. J.
Rudolph Philip Miller, New York City.
Charles Hamilton Mitchell, Niagara Falls, Ont., Canada.
Arthur Marquis Scripture, New Hartford, N. Y.

The Secretary announced the election of the following candidates by the Board of Direction, on January 5th, 1904:

As Juniors.

Walter Loring Anthony, Providence, R. I.
Ralph Hamlin, New York City.
George Gallagher Hopkins, Jr., Brooklyn, N. Y.
Leroy Littlefield Hunter, Pittsburg, Pa.
Boudinot Gage Leake, Ft. Worth, Tex.
Henry McBurney, Philadelphia, Pa.

The Secretary announced the following deaths:

James Peter Bogart, elected Junior January 4th, 1882; Member July 3d, 1895; died December 24th, 1903.

Edward Bernard Ives, elected Member April 5th, 1893; died December 30th, 1903.

Clark Fisher, elected Member October 19th, 1870; died December 31st, 1903.

The Secretary announced the details of the programme of the Annual Meeting.

Adjourned.

January 20th, 1904.—The minutes of this, the Annual Meeting, will be printed in the *Proceedings* for February, 1904.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 5th, 1904.—8.30 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Craven, Croes, Freeman, Jackson, Kuichling, Osgood, Pegram, Schneider and Swain.

A report was received from a Special Committee, recommending that this Society undertake the organization and management of an International Engineering Congress, to be held in St. Louis during the week beginning October 3d, 1904. The recommendation of the Committee was adopted as the action of the Board.

The Annual Report of the Board to the Society was adopted.

The following report was received:

"To the Board of Direction,
American Society of Civil Engineers:

"The Committee appointed to recommend the award of prizes for papers in *Transactions* for the year ending July, 1903, respectfully makes the following report:

"Your Committee having carefully considered all of the papers in Volumes XLIX and L of *Transactions* recommends that no award of The Norman Medal be made this year.

"The Committee recommends that The Thomas Fitch Rowland Prize be awarded to Paper No. 954, 'The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey,' by George W. Fuller, Assoc. M. Am. Soc. C. E.

"The Committee further recommends that The Collingwood Prize for Juniors be awarded to Paper No. 939, 'The Footbridge for Building the Cables of the New East River Bridge,' by Isaac Harby, Jun. Am. Soc. C. E.

"All of which is respectfully submitted.

"MANSFIELD MERRIMAN,
"E. P. DAWLEY,
"W. KIERSTED,
"*Committee.*

"DECEMBER 5TH, 1903."

The recommendations of the Committee were adopted as the action of the Board.

Letters were presented from the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, stating that they had arranged to establish headquarters in the Machinery Hall Building, and Electricity Building, respectively, and inviting the members of this Society to avail themselves of these headquarters.

The following resignations were accepted, taking effect December 31st, 1903:

James Imbrie Miller, Jacob Herbert Sawyer, Harry Van Vleck Gifford, Henry Garfield Perring.

J. L. Van Ornum, M. Am. Soc. C. E., was added to the Committee of the Society in charge of the Society's exhibit and headquarters for engineers at St. Louis.

Arguments for and against the joining of this Society in the proposed Union Engineering Building, for presentation to the Annual Meeting, were considered.

Applications were considered and other routine business transacted.

Eleven Associate Members were transferred to the grade of Member, and six candidates for Junior were elected *

* See pages 2 and 3.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, February 3d, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Method Used by the Railroad Commission, of Texas, in Valuing Railroad Properties, Under the Stock and Bond Law," by R. A. Thompson, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, February 17th, 1904.—8.30 P. M.—At this meeting a paper, entitled "Freezing as an Aid to Excavation in Unstable Material," by James H. Brace, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

A Committee of the Board of Direction is now arranging a programme, with a view to making this Convention an International Meeting of Engineers, for the presentation and discussion of timely subjects of professional interest.

As the details of the arrangements are developed, they will be announced in *Proceedings.*

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an engineering exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

Robert Moore, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
Edward C. Carter, M. Am. Soc. C. E., Chicago, Ill.
Mordecai T. Endicott, M. Am. Soc. C. E., Washington, D. C.
James L. Frazier, " " Frankfort, Ind.
William Jackson, " " Boston, Mass.
Emil Kuichling, " " New York, N. Y.
J. L. Van Ornum, " " St. Louis, Mo.
John F. Wallace, " " Chicago, Ill.
H. J. Pfeifer, Assoc. M. Am. Soc. C. E., St. Louis, Mo., *Secretary.*

INTERNATIONAL ENGINEERING CONGRESS.

The Board of Direction has decided to organize and conduct an International Engineering Congress, to be held in St. Louis, Mo., during the week beginning October 3d, 1904. A committee appointed for the purpose has formulated a general plan for this Congress, the essential features of which are as follows:

A number of subjects of live interest have been chosen and on each of these, a specialist is to be selected in America, and as far as possible in each foreign country, and asked to contribute a paper giving a succinct review of the progress in this special branch of Civil Engineering, during the past ten years, with a summary of present practice.

These papers will be printed in advance, and each subject will be open to discussion at the Congress, at which no papers will be read. The papers, together with the discussion upon them, will be collated and published in one or more volumes, which will be furnished free of charge to each Member of the Society, and to such other persons as become Members of the Congress by the payment of $5.

Already the acceptances of the invitations to prepare papers issued by the Committee indicate a gratifying interest, and a large attendance is expected, inasmuch as the Society Convention will be held at the same date, and the expected visit of Members of the Institution of Civil Engineers of Great Britain will be so timed that all who visit us in the Society House in New York will have an opportunity to attend.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1903.

Presented at the Annual Meeting, January 20th, 1904.

The Board of Direction, in compliance with the Constitution of the Society, presents its report for the year ending December 31st, 1903.

MEMBERSHIP.

The changes in membership are shown in the following table:

Grade.	Jan. 1st, 1903.			Jan. 1st, 1904.			Losses.				Additions.		Totals.	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.
Honorary Members	1	8	9	1	8	9	..	..	..	..	....	....	....	....
Corresponding Members	....	2	2	....	2	2	..	..	..	..	....	....	....	....
Members	312	1 263	1 575	335	1 322	1 657	..	6	13	25	*34	92	44	126
Associate Members	192	522	714	209	600	809	32	1	3	3	†33	101	39	134
Associates	43	76	119	48	77	125	1	2	..	1	‡2	8	4	10
Juniors	107	153	260	117	176	293	36	3	15	2	....	89	56	89
Fellows	10	23	33	8	21	29	..	..	..	4	....	....	4	....
Totals	665	2 047	2 712	718	2 206	2 924	69	12	31	35	69	290	147	359

* 32 Associate Members and 2 Juniors.
† 1 Associate and 32 Juniors.
‡ 2 Juniors.

It will be seen that the net increase during the year was 212, which is the largest yearly increase in the history of the Society. Previous to 1899, the yearly increase reached 100 in four cases only, no two of which were consecutive; since that date, the net yearly increase has been as follows:

1899	103
1900	138
1901	190
1902	185
1903	212
Total net increase for five years	828
Average net yearly increase for the past five years	166
Average net yearly increase from 1869 to 1898, inclusive	62

The total number of applications received during the year was 432.

The Board has taken action as follows:

Passed to ballot as Member	149	
Passed to ballot as Associate Member	151	
Passed to ballot as Associate	1	
		301
Transferred from Associate Member to Member	6	
		6
Elected Associate	10	
Elected Junior	99	
		109
Total		416
Applications now awaiting action		92

In explanation of the foregoing figures, it should be stated that an amendment to the Constitution, which became operative on November 6th, 1903, places the responsibility for transfers from all grades, except that of Junior, in the hands of the Board. The time has been short since this amendment went into effect, but the Board wishes to state that at least one of its provisions, under which all applications are presented for admission and not for a particular grade, has already demonstrated great improvement over the old method; the opinions of members, whether endorsers or not, are now unhampered by the fact that applicants have applied for a particular rating, and are given much more freely.

The losses by death reported during the year number 35. They are as follows:

Members: Sylvanus Thayer Abert, Frederick Winn Bond, William Warren Card, Charles Frederick Dunham, William Buel Franklin, Alphonse Fteley, Estevan Antonio Fuertes, Charles Ezra Greene, Edward Appleton Greene, George Richardson Hardy, Edward Bernard Ives, Charles Andrews Knowlton, Edmund Dorman Libby, Charles Cyril Martin, George Shattuck Morison, Henry Grant Morse, Cornelius Palmer, John Austin Patterson, Watson Wellman Rich, Alfred L. Rives, Elnathan Sweet, William George McNeill Thompson, Robert Henry Thurston, Eugene Vanderpool, Reuel Willard Ware.

Associate Members: John Walker Barriger, Jr., Robert Delano Cushing, Robert Blum Olney.

Associates: John Elfreth Watkins.

Juniors: Benjamin Harrison Flynn, Norman Smith Latham.

Fellows: Victor M. Clement, Walter S. Gurnee, Benjamin Franklin Jones, William Johnston Taylor.

LIBRARY.

The accessions to the Library during the year are shown in the following table:

ACCESSIONS DURING THE YEAR 1903.

	Bound Volumes.	Unbound Volumes.	Specifications.	Maps, Photographs and Drawings.	Total.
Donations—					
In answer to special requests...........	457	1 285	1	1	1 744
From publishers.....	78	4	1	....	83
Eng. News Pub. Co..	54	170	25	....	249
Hammond Bequest...	55	20	....	....	75
In regular course....	352	507	178	311	1 348
Exchange of duplicates.	97	166	....	....	263
By purchase....... ..	159	29	....	....	188
Totals...........	1 252	2 181	205	312	3 950

In addition to the above, there have been received 652 duplicates, and 28 separate numbers to complete files of periodicals, neither of which can appear as accessions.

The Library now contains:

Bound volumes..............................	12 582
Unbound volumes............................	25 907
Specifications................................	5 863
Maps, photographs and drawings.............	3 312
Total..................................	47 664*

The total number of titles in the Library is 19 853.

During the year, 228 volumes have been bound, and 29 bound volumes which were duplicates were received and have replaced previously unbound volumes.

The following amounts have been expended upon the Library during the year:

Purchase of books, 188 volumes................	$636.33
Express charges, etc..........................	42.54
Binding 228 volumes..........................	260.15
Fixtures and supplies.........................	4.71
Total..................................	$943.73

* The total number of accessions to date is 51 547, inasmuch as 3 883 pamphlets are bound in volumes with other pamphlets, and each such volume can be given in the above list once only.

The value of the accessions to the Library during the year is as follows, each accession having been valued separately, as received:

3 762 Donations and exchanges (estimated value)	$2 121.11
188 Volumes purchased (cost)	636.33
Binding 228 volumes	260 15
Total	$3 017.59

The attendance at the Library has increased materially during the year, and a number of searches have been made for members who could not consult the Library in person.

During the year, the second volume of the Catalogue of the Library was prepared and published.

PUBLICATIONS.

During the year the usual ten numbers of *Proceedings* and two volumes of *Transactions* have appeared.

In the *Proceedings*, the list of references to current engineering literature has covered 81 pages, containing 3 489 classified references to 65 periodicals.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 121 753 copies, the cost of which to the Society, for paper and presswork only, has been $14 401.85.

During the year, 3 895 volumes of the Society publications have been bound, for members and others, in the standard half-morocco or cloth bindings.

The extra publications during the year have been: Vol. 2 of the Catalogue of the Library; an advance issue of the "Report in Full of the Annual Convention"; a pamphlet entitled "The House of the American Society of Civil Engineers"; and circulars relating to a proposed Union Engineering Building.

SUMMARY OF PUBLICATIONS FOR 1903.

	Issued.	Edition.	Total Pages.	Plates.	Cuts.
Transactions (Volumes)*	2	3 200	1 005	54	172
Proceedings (Monthly Numbers)**	10	3 275	1 717	67	247
Advance copy of Report of Convention	1	3 000	80	....	....
Constitution and List of Members	1	3 500	213	....	1
Catalogue of Library	1	3 200	293	....	....
Society House Pamphlet	1	3 200	21	15	....
Totals	16	......	3 329	136	420

* Includes Indexes and Tables of Contents.
** " " Tables of Contents and Advertisements.

The cost of publications has been:

For Paper, Printing, Binding, etc., *Transactions* and *Proceedings*		$9 814.88
For Plates and Cuts		1 451.50
For Boxes, Mailing Lists, Copyright and Sundry Expenses		389.27
For Commission on Advertisements		182.98
For 13 025 copies of Memoirs and Papers		944.46
For List of Members		897.57
For Library Catalogue		1 378.30
For Society House Pamphlet		224.80
For Refunds of Payments for Advertising		141.00
Total		$15 424.76
Deduct amount received for advertisements	$1 201.00	
Deduct amount received for sale of publications	2 901.94	
		4 102 94
Net cost of Publications for 1903		$11 321.82

MEETINGS.

During the year, 23 meetings have been held, as follows: Annual Meeting, 1; at the Annual Convention, 4; regular semi-monthly meetings, 18.

At these meetings, there were presented 20 formal papers, 4 of which were illustrated with lantern slides, and 7 topics for informal discussion.

The Thirty-fifth Annual Convention was held at the Battery Park Hotel, Asheville, N. C., at which the registered attendance numbered 122 members and 133 guests.

MEDALS AND PRIZES.

For the year ending with the month of July, 1902, Prizes were awarded as follows:

The Norman Medal to Gardner S. Williams, M. Am. Soc. C. E., Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E., for their paper entitled "Experiments at Detroit, Mich., on the Effect of Curvature upon the Flow of Water in Pipes."

The Thomas Fitch Rowland Prize to William W. Harts, M. Am. Soc. C. E., for his paper entitled "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government."

No award of the Collingwood Prize for Juniors was made.

FINANCES.

The attention of members is invited to the Secretary's statement of receipts and disbursements, and to the general balance sheet which accompanies it, in which the very satisfactory financial condition of the Society appears.

CONCLUSION.

In concluding the report, the Board is glad to be able to summarize the general condition of the Society as satisfactory in every way. Notwithstanding the payment of $10 000 of the mortgage indebtedness, and the appropriation and payment of $3 000 to a Special Committee for the establishment of an Engineering Headquarters and an Engineering Exhibit by the Society at the St. Louis Exposition, the balance on hand is somewhat larger than that of last year. In addition to this, the Board has felt justified, after the other National Engineering Societies had declined to co-operate in the project, in assuming the entire responsibility for the expense of holding an International Engineering Congress, in connection with the Exposition. This Congress will be held during the week beginning October 3d, 1904, and the visit of members of the Institution of Civil Engineers, which has been arranged for, will be so timed that, after a brief stay in New York as the guests of the Society, all who so desire will be able to attend. It is hoped that all members of the Society will aid the Committee which has been appointed by the Board to organize and conduct this Congress.

The Board has devoted much time to the effort to carry out the instructions of the Asheville Convention, in the preparation of the project for a Union Engineering Building for presentation to the Society. Everything possible has been done to place the project on such a basis that all members may have an opportunity to vote upon it, and the result will be placed before this Annual Meeting, together with arguments for and against participation by the Society. The Board makes no recommendation in this matter, believing that the Society at large should decide what is probably the most important question which it has yet been called upon to determine.

The reports of the Secretary and the Treasurer are appended.

By order of the Board of Direction.

CHAS. WARREN HUNT,

Secretary.

NEW YORK, January 5th, 1904.

GENERAL BALANCE SHEET, DECEMBER 31st, 1903.

ACCOMPANYING REPORT OF THE SECRETARY.

Assets.			Liabilities.	
Building and Lot (cost)		$191 730.26	Dues for 1904, paid in advance	$13 281.11
Furniture (cost)		16 232 64	Mortgage Debt	55 000.00
Publications on hand (inventoried cost, value)		14 401.85	Funds invested in Society House and Lot, and Library	235 696.51
Library:				
Cash expended for Books, etc.	$8 721.36			
Estimated Value of Donations	42 721.84			
		51 443.20		
Due from Members	$2 373.96			
" " Non-Members	905.17			
		3 279.13		
Cash		26 890.54		
		$303 977.62		$303 977.62

NEW YORK, 20th January, 1904.—We have examined the books and accounts of the American Society of Civil Engineers, and certify that the foregoing Balance Sheet is in accordance therewith, as of 31st December, 1903; and, in our opinion, correctly states the condition of the Society's affairs as shewn by the books at that date.

MENZIES, ROBERTSON & CO.,
Chartered Accountants.

REPORT OF THE SECRETARY, FOR THE

To the Board of Direction of the

Gentlemen,—I have the honor to present a statement of Re-
December 31st, 1903. I also append a general balance sheet showing
New York, January 5th, 1904.

Receipts.

Balance on hand December 31st, 1902, in Bank and Trust Company and in hands of the Treasurer		$26 297.39
Entrance Fees	$7 025.00	
Current Dues	32 930.35	
Past Dues	1 192.43	
Advance Dues	13 281.11	
Certificates of Membership	281.50	
Badges	1 249.56	
Sales of Publications	2 901.94	
Advertisements	1 201.00	
Interest	647.27	
Library	73.20	
Annual Meeting	1 042.00	
Binding	3 752.49	
Miscellaneous	59.88	
		6 5637.73
		$91 935.12

YEAR ENDING DECEMBER 31ST, 1903.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

ceipts and Disbursements for the fiscal year of the Society, ending
the condition of the affairs of the Society.

Respectfully submitted,

CHAS. WARREN HUNT,
Secretary.

DISBURSEMENTS.

Salaries of Officers	$8 200.00	
Clerical Help	9 423.77	
Caretaking	1 794.42	
Publications	15 100.78	
Postage	3 436.48	
General Printing and Stationery	1 889.62	
Badges	1 112.56	
Certificates of Membership	208.40	
Binding	2 066.60	
Library	943.73	
Maintenance of House	542.47	
Heat, Light and Water	1 242.14	
Betterments	40.00	
Furniture	568.34	
Annual Meeting	1 153.30	
Convention	349.37	
Prizes	146.10	
Advertising Commissions	182.98	
Interest and Insurance	2 400.00	
Louisiana Purchase Exposition	3 000.00	
Committee Work	217.96	
Bond and Mortgage	10 000.00	
Current Business	708.00	
Engineering Congress	3.74	
Refunds	166.00	
Petty Expenses	147.82	
		$65 044.58
Balance on hand, December 31st, 1903:		
In Union Trust Company	$19 162.50	
In Garfield National Bank	6 743.04	
In hands of Treasurer	985.00	
		26 890.54
		$91 935.12

REPORT OF THE TREASURER.

In compliance with the provisions of the Constitution, the Treasurer presents the following report for the year ending December 31st, 1903:

Balance on hand December 31st, 1902			$26 297.39
Receipts from current sources, January 1st to December 31st, 1903			65 637.73
Payment on audited vouchers for current business, January 1st to December 31st, 1903		$52 044.58	
Payment on principal of Bond and Mortgage		10 000.00	
Cash advanced to Committee on Exhibits and Engineering Headquarters, Louisiana Purchase Exposition		3 000.00	
Balance on hand December 31st, 1903:			
In Union Trust Company	$19 162.50		
In Garfield National Bank	6 743.04		
In hands of the Treasurer.	985.00		
		26 890.54	
		$91 935.12	$91 935.12

Respectfully submitted,

JOS. M. KNAP,
Treasurer, Am. Soc. C. E.

NEW YORK, January 5th, 1904.

ACCESSIONS TO THE LIBRARY.

From December 9th to January 12th, 1904.

DONATIONS.*

WORM AND SPIRAL GEARING.

By Frederick A. Halsey. Second Revised and Enlarged Edition. Boards, 6 x 4 ins., 90 pp., illus. New York, D. Van Nostrand Company, 1903. 50 cents.

It is stated in the preface that justification for the republication of the contents of this book is found in the still prevalent opinion among designers of machinery that worm gearing is necessarily short lived and of low efficiency, and in the fact that the methods of laying out spiral gearing are not as widely understood as the merit and convenience of that form of gearing make desirable. The author believes that the theory of worm gearing is well fortified by the collection of facts from experience given herein, and it points out the procedure to be followed in order to insure durability and efficiency. Both analytical and graphical methods of laying out spiral gearing are given. The solutions relate exclusively to gears having their shafts at right angles. Some of the chapter headings are: Worm Gearing; Theory of Worm Efficiency; Experimental Corroboration of the Theory; Examples from Practice; Limiting Speed and Pressure; Step Bearings; Spiral Gears Compared with Spur Gears; The Speed Ratio; The Preliminary Solution; The Lengths of the Normal Helixes; A Practical Example; Final Solution by Changing the Center Distance; Finding the Pitch of the Tooth Helix; The Selection of the Cutter.

TELEPHONY.

A Manual of the Design, Construction, and Operation of Telephone Exchanges. In Six Parts. Part IV. The Construction of Aerial Lines. By Arthur Vaughan Abbott. Boards, 7 x 6 ins., 14 + 263 pp., illus. New York, McGraw Publishing Company, 1903. $1.50.

Owing to the present increase in quantity of pole line and great decrease in the ratio of wire mileage to line mileage, the design of the pole line of 1903 differs radically from that of 1893, and this volume is an effort to deal with the conditions of the present, with the idea of devoting little space to descriptive matter which is chiefly academic in its nature. Following the plan of the previous parts, the subject is treated in a manner which it is hoped will be of value to the man who is bearing the heat and burden of the day, particularly by supplying much needed information as to costs of construction and the proper rates of maintenance and depreciation. A specification is framed on lines which it is hoped are broad enough to cover all but exceptional cases. The Contents are: Introduction; The Loaded Line; Routes and Rights of Way; Poles; Stresses and the Strength of Poles; Wire Supports and Wire; Distribution; The Cost of Aerial Lines; Disturbances on Telephone Lines; Specification for the Construction of Aerial Lines. There is an index of three pages.

A CALENDAR OF INVENTION AND DISCOVERY.

Compiled by John Cassan Wait. Morocco, 6 x 5 ins., unpaged, illus. McGraw Publishing Company, New York, 1903. Price of cloth copy, $1.00. (Donated by the Author.)

In this book each page of reading matter contains brief biographies of two noted persons who have contributed materially to the industrial progress of the world, and gives briefly the discoveries or inventions made or great works erected or created by them. It also contains two to four poetical quotations, from classic English literature, describing or illustrating the sciences, industrial arts, invention or discovery. The selections have been chosen and applied appropriately to the inventor or discoverer or to the subject in which he wrought or studied. At the bottom of each page are given, in chronological order, the important events leading up to or resulting from the invention or discovery described. The work is intended as an encyclopedia of great men and their doings. It is indexed as to poetry, persons and things.

---

* Unless otherwise specified books in this list have been donated to the Library by the publisher.

FOWLER'S ELECTRICAL ENGINEER'S YEAR BOOK AND DIRECTORY OF LIGHT, POWER, & TRACTION STATIONS. 1904.

Boards, 6 x 4 ins., 539 pp., illus. Manchester, Scientific Publishing Company. 1 shilling 6 pence, net.

During the past year the Institution of Electrical Engineers revised the general rules for wiring, and these are embodied in this edition of the Year Book, as are also the various Board of Trade Regulations and Statutory Rules, relating to Tramways, Light Railways and Electric Lighting. Numerous tables of data have been interpolated, with a view of enriching the text which in many parts has been largely rewritten, as in the case of the sections on "Measuring Instruments," "Electric Distribution," "Meters," "Dynamos," etc., while new matter on Polyphase Transmission and Induction Motors is included. The yearly revision has been made in the directory of electric light, power and traction stations of the United Kingdom, which forms an annually increasing section of the book The particulars of station plant, equipment, and staff of more than five hundred installations are given, and an effort has been made to bring the information up to date.

AMERICAN METER PRACTICE.

By Lyman C. Reed. Cloth, 9 x 6 ins., 196 pp., illus. New York, McGraw Publishing Company, 1903. $2.00.

In this book an effort has been made to outline the underlying principles of operation and practice, and leave the minor details to be worked out to suit local conditions. In describing only a few meters the author's object is to select one each of well known and representative types. Chapter XIII, on How to Read Meters, is intended to interest the consumer of power who is not a technical man. It will enable him to figure out and check up his meter bills. The chapter headings are: Measurement of Power in Direct Current Circuits; Measurement of Power in Alternating Current Circuits; Meter Selection; Torque and Friction; The Edison Chemical Meter; The Thomson Recording Wattmeter; The Duncan Recording Wattmeter for Alternating Current; The Duncan Wattmeter for Direct Current; The Stanley Recording Wattmeter; The Guttman Wattmeter; The Westinghouse Induction Meter; General Management of the Meter Department; Records; Testing; General Policy; Reading Meters; Value of Losses in Meters Relative to Income; Differential Rating; Elements of Photometry.

EXPERIMENTAL RESEARCHES ON REINFORCED CONCRETE.

By Armand Considère. Translated and Arranged by Leon S. Moisseiff, Assoc. M. Am. Soc. C. E. With an Introduction by the Translator. Cloth, 9 × 6 ins., 9 + 188 pp., illus. New York, McGraw Publishing Company, 1903. $2.00.

The researches, the results of which are given in this book, were undertaken in the year 1898, and cover the time from that date to the end of 1902. The first published report of the results obtained is found in a paper by the experimenter before the French Academy of Sciences at the end of 1898. As the work proceeded M. Considère published a number of papers containing the results of his labors. This book consists of a compilation of these publications arranged and classified so as to make, as far as possible, one coherent treatise. It has been the intent of the translator to adhere to the author's wording and treatment, avoiding at the same time unnecessary repetitions. The chapters of the book, as will be seen, follow in general, the titles of the several papers as they were published, and also their chronological order. This arrangement appeared to be the best, containing, as each paper does, the further development of the author's ideas. The Contents are: Reinforced Concrete in Bending; The Deformation and Testing of Reinforced Concrete Beams; Effects of Changes in Volume of Concrete; Tensile and Compressive Resistance of Concrete; Resistance of Concrete to Shearing and Sliding; Effects of Cracks on Stresses and Deformations; The Compressive Resistance of Reinforced and Hooped Concrete.

THE MECHANICAL ENGINEER'S REFERENCE BOOK.

A Hand-Book of Tables, Formulas and Methods for Engineers, Students, and Draftsmen. By Henry Harrison Suplee, M. Am. Soc. M. E. Leather, 7 × 4 ins., 12 + 834 pp., illus. Philadelphia and London, J. B. Lippincott Company, 1904. $5.50 net. Without thumb index, $5.00.

The preface states that the many and varying rules and formulas in connection with mechanical engineering have been examined, and only those which, in the judgment of the author, are most generally applicable have been given. As the metric

system has been under active discussion of late, many of the tables have been presented in both British and metric units. Among these tables may be mentioned the metric steam tables, which render it convenient to make steam computations in the metric system. This work is intended to be a successor to the well-known pocket-book written many years ago by the late John W. Nystrom. Certain information therein contained has been utilized, with such modifications as are necessary to meet the engineering problems and needs of the day. The Contents are: Mathematics; Mechanics; Materials of Engineering; Strength of Materials; Machine Design; Heat; Air; Water; Fuel; Steam; Steam Boilers; Steam Engines; Internal-Combustion Motors; Electric Power; The Cost of Power; Works Management; Appendix. The volume is supplied with a patent thumb index intended to facilitate reference.

THE POLAR PLANIMETER AND ITS USE IN ENGINEERING CALCULATIONS. Together with Tables, Diagrams and Factors for the Immediate Adjustment of the Instrument for the Solution of Problems Involving: The Measurement of Large and Small Areas, Average or Mean Height of Indicator and Similar Diagrams, Determination of Centre of Gravity, Measurement of Volumes of Railway and Canal Excavation, Volumes in Grading and Dredging Operations, Volumes in Reservoir and Similar Design and Construction, Quantities and Volumes of Brickwork, Weights of Iron and Other Metals in Construction, Measurement of Displacement Diagrams, etc., etc., etc. By J. Y. Wheatley. Cloth, 9 x 6 ins., 114 pp., illus. New York, Keuffel & Esser Co. $3.00. (Donated by Carl M. Bernegau.)

The publication of this work is the direct result of the author's experience at the time of his first purchase of a planimeter, as he was unable to find any treatise on the subject which would give him the information necessary to make an intelligent use of the instrument. This led at once to a study, first of the theory of the planimeter, and then of the engineering problems to the solution of which that theory could be applied.

Gifts have also been received from the following:

Am. Inst. Min. Engrs. 1 pam.
Atlantic Coast Line R. R. Co. 2 pam.
Binghamton, N. Y.—City Engr. 1 pam.
Boston, Mass.—Transit Comm. 1 bound vol.
British Fire Prevention Committee. 4 pam.
Cleveland, Ohio—City Council. 1 bound vol
Cole, W. W. 1 vol.
Cunningham, A. C. 1 pam.
Fisk, W. L. 1 map, 1 pam.
Follett, W. W. 2 bound vol.
Great Britain—Patent Office. 9 pam., 1 vol.
Henderson, J. B. 7 pam.
Indian Midland Ry. Co., Ltd. 1 pam.
Inst. of Civ. Engrs. 2 bound vol., 1 pam.
Inst. of Min. & Metallurgy. 10 bound vol.
Iowa Central Ry. Co. 2 pam.
Kansas City Southern Ry. Co. 1 pam.
Ky.—Inspector of Mines. 1 bound vol.
Lindenthal, Gustav. 5 pam., 3 drawings.
London, Ont.—Water Commrs. 1 pam.
Long Island R. R. Co. 1 pam.
Low, Emile. 1 blue print.
Madras—Pub. Works Dept. 1 pam.
Mead, Elwood. 1 pam.
New England Assoc. of Gas Engrs. 1 bound vol.
New South Wales—Ry. Commrs. 1 bound vol.
N. Y.—State Library. 4 bound vol.
Newlands, F. G. 1 pam.
Oesterr. Ingenieur- und Architekten-Verein. 1 pam.
Osgood Dredge Co. 3 photo.
Poetsch, C. J. 1 vol.
Ry. Signal Assoc. 1 pam.
Richardson, Clifford. 1 pam.
Rutland R. R. Co. 1 pam.
South Australia—Rys. Commr. 1 pam.
Tonindustrie-Zeitung. 1 bound vol., 1 vol.
U. S. Commr. of Education. 1 bound vol.
U. S. Commr. of Navigation. 1 bound vol.
U. S. Geological Survey. 2 bound vol., 4 pam.
U. S. Ordnance Dept. 12 bound vol.
U. S. War Dept. 18 specif.
U. S. War Dept. Lib. 8 bound vol.
U. S. Weather Bureau. 1 pam.
Università Romana. 1 vol.
Victoria—Agent General. 12 bound.
Waddell, Montgomery. 1 vol.
Western Australia—Commr. of Rys. 1 pam.

BY PURCHASE.

The Electrician: A Weekly Illustrated Journal of Electrical Engineering, Industry and Science. Oct. 25, 1901–Dec. 25, 1903. 4 vol. London, 1901–03.

A Text-Book of Electrical Machinery. Vol. I. Electric, Magnetic, and Electrostatic Circuits. By Harris J. Ryan, M. Am. Inst. E E., M. Am. Soc. M. E.; Henry H. Norris, Assoc. M. Am. Inst. E. E., and George L. Hoxie, Assoc. M. Am. Inst. E. E., Jun. Am. Soc. M. E. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1903.

Handbuch der Ingenieurwissenschaften. Vol. I, Pt. 4. Dritte vermehrte Auflage. Leipzig, Wilhelm Engelmann, 1903.

Die Eisenkonstruktionen der Ingenieur-Hochbauten. Ein Lehrbuch zum Gebrauche an technischen Hochschulen und in der Praxis. Von Max Foerster. Ergänzungsband zum Handbuche der Ingenieurwissenschaften. Zweite, verbesserte und vermehrte Auflage. Leipzig, Wilhelm Engelmann, 1903.

The Tribune Almanac and Political Register, 1904. New York, The Tribune Association, 1904.

The Purification of Sewage and Water. By W. J. Dibdin. Third Edition, Revised and Enlarged. London, The Sanitary Publishing Company, Limited; New York, D. Van Nostrand Company, 1903.

Wood. A Manual of the Natural History and Industrial Applications of the Timbers of Commerce. By G. S. Boulger. London, Edward Arnold, 1902.

De l'Emploi du Bouclier dans la Construction des Souterrains. Par Raynald Legouëz. Paris, Baudry et Cie., 1897.

SUMMARY OF ACCESSIONS.

December 9th, 1903, to January 12th, 1904.

Donations (including 17 duplicates)	136
By purchase	11
Total	147

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
Beugler, Edwin James. Res. Engr., The Boston Terminal Co., 220 South Station, Boston, Mass.	Jun. Assoc. M. M.	June 19, 1891 Feb. 1, 1899 Jan. 5, 1904
Bloss, Richard Parkhurst. Res. Engr., The Duncan Co., Mechanicsville, N. Y.		Jan. 6, 1904
Brownell, Ernest Henry. Civ. Engr., U. S. N., Navy Yard, Portsmouth, N. H.	Assoc. M. M.	Jan. 1, 1896 Jan. 5, 1904
Burden, James. 3 Locust Ave., Troy, N. Y.	Assoc. M. M	Feb. 5, 1902 Jan. 5, 1904
Coleman, Frederick Albert. Supt., Bellington & Northern R. R. Co.; Valley Coal & Coke Co., Bellington, W. Va.	Jun. Assoc. M. M.	April 4, 1893 April 5, 1899 Dec. 1, 1903
Dose, Henry Frederick. Res. Engr., Penn., N. Y. & L. I. R. R. Co., East River Div., 225 West 33d St., New York City		Jan. 6, 1904
Fay, Frederic Harold. Asst. Engr., Eng. Dept., 60 City Hall, Boston, Mass.	Jun. Assoc. M. M.	Oct. 2, 1894 April 2, 1902 Jan. 5, 1904
Green, Hubert Edward. Engr., U. S. Geological Survey, Div. of Hydrography, 431 Rialto Bldg., San Francisco, Cal		Dec. 2, 1903
Kops, Julian de Bruyn. Civ. Engr. and Archt., 18 Board of Trade Bldg., Savannah, Ga.	Assoc. M. M.	April 4, 1894 Jan. 5, 1904
Mead, Charles Adriance. 165 Wildwood Ave., Upper Montclair, N. J	Assoc. M. M.	April 5, 1899 Jan. 5, 1904
Mitchell, Charles Hamilton. Asst. Engr., Ontario Power Co., Niagara Falls, Ont., Canada.	Assoc. M. M.	June 4, 1902 Jan. 5, 1904
Scripture, Arthur Marquis. New Hartford, N. Y.	Assoc. M. M.	June 3, 1896 Jan. 5, 1904

ASSOCIATE MEMBERS.

Allen, Walter Hinds. Civ. Engr., U. S. N., Navy Yard, Brooklyn, N. Y.	Jun. Assoc. M.	May 1, 1900 Nov. 4, 1903
Barrows, Harold Kilbreth. Assoc. Prof., Civ. Eng., Univ. of Vermont, Burlington, Vt		Jan. 6, 1904
Bowman, Joseph Hockman. Chf. Engr., Pan-American R. R., Tonalá, Chiapas, Mexico		Dec. 2, 1903
Campbell, Arthur Ira. Div. Engr., St. L. & San Fran. R. R. Co., Granite Blk., St. Louis, Mo.		Dec. 2, 1903
Cole, Herbert Nichols. 721 Van Buren St., Milwaukee, Wis.		Jan. 6, 1904
Cresswell, Herbert Augustine. Res. Engr., Western Australian Govt. Rys., Geraldton, Western Australia		Oct. 7, 1903
Cummings, Elmore David. 918 East 20th St., Baltimore, Md.		Nov. 4, 1903

	Date of Membership.
GLAZIER, WILLIAM LEONARD. Engr. and Supt., Newport Water-Works, Newport, Ky	Oct. 7, 1903
HAMLIN, WILLIAM ELIOT. Chf. Engr., Frank B. Gilbreth, Gen. Contr., Park Row Bldg., New York City	Dec. 2, 1903
MURRAY, CHARLES WARREN. City Engr. and Supt. of Water-Works, City Hall Bldg., Americus, Ga	Dec. 2, 1903
PFAU, JULIUS WELCH. 510 Second Ave., Troy, N. Y	Dec. 2, 1903

ASSOCIATES.

COLBY, SAFFORD KINKEAD. Contr. Engr. and Mgr., Eastern Office, The Pittsburg Reduction Co., 99 John St., New York City	Jun.	Mar. 5, 1895
	Assoc.	Jan. 6, 1904

JUNIORS.

BECKER, SYLVANUS A. Box 732, Connellsville, Pa	Dec. 1, 1903
CHADBOURNE, EDWARD MERRIAM. Chf. Engr., Albuquerque Traction Co., Albuquerque, N. Mex	Nov. 3, 1903
COTTON, MILES PENNER. C. P. R. R. Constr. Dept., Winnipeg, Man., Canada	Oct. 6, 1903
FOSS, JOHN HARRISON. With Hamakua Ditch Co., Huelo, Maui, Hawaii	Dec. 1, 1903
GILMAN, CHARLES EDWARD. Asst. Engr., Bay Cities Water Co., 10th Floor, Mutual Savings Bank Bldg., San Francisco, Cal	Oct. 6, 1903
HAEHL, HARRY LEWIS. Asst. Engr., Bay Cities Water Co., Coyote, Santa Clara Co., Cal	Oct. 6, 1903
HAMLIN, RALPH. Structural Designer, International Paper Co., 30 Broad St., New York City	Jan. 5, 1904
HOPKINS, GEORGE GALLAGHER, Jr. Insp. for the N. Y. Board of Fire Underwriters. Address, 350 Washington Ave., Brooklyn, N. Y	Jan. 5, 1904
MCBURNEY, HENRY. 1409 Locust St., Philadelphia, Pa	Jan. 5, 1904
TATLOCK, JAMES LLOYD. Asst. Engr., Sewer Comm., City Hall, New Rochelle, N. Y	Sept. 1, 1903

RESIGNATIONS.

MEMBERS.

	Date of Resignation.
HOECH, THEODOR GOTTLIEB	Dec. 31, 1903
MILLER, JAMES IMBRIE	Dec. 31, 1903

ASSOCIATE MEMBERS.

CRABBS, CLARENCE LINCOLN	Dec. 31, 1903

ASSOCIATES.

SAWYER, JACOB HERBERT	Dec. 31, 1903

DEATHS.

BOGART, JAMES PETER........Elected Junior, January 4th, 1882; Member, July 3d, 1895; died December 24th, 1903.

FISHER, CLARK...............Elected Member, October 19th, 1870; died December 31st, 1903.

IVES, EDWARD BERNARD......Elected Member, April 5th, 1893; died December 30th, 1903.

REED, WILLIAM W...........Elected Fellow, December 20th, 1872; died January 10th, 1904.

SHANKS, THOMAS PEARMAN....Elected Member, May 2d, 1888; died January 7th, 1904.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(December 9th, 1903, to January 12th, 1904.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(73) *Electrician*, London, England, 18c.

LIST OF ARTICLES.

Bridge.

Reconstruction of a Bridge on the Midland Railway, across the River Trent.* Frank Horace Frere, Assoc. M. Inst. C. E. (63) Vol. 154.
The Protection Works of the Kaisar-i-Hind Bridge over the River Sutlej, near Ferozepur. Amyas Morse, M. Inst. C. E. (63) Vol. 154.
The Superstructure for the Manhattan Bridge across the East River at New York City.* (13) Dec. 10.
Wabash Steel Concrete Construction.* (40) Dec. 11.
Moving a Seine Bridge.* (12) Dec. 11.
Concrete-Steel Arch Bridge for the C. B. & Q. Ry., at Plano, Ill.* (18) Dec. 12; (15) Dec. 11; (14) Jan. 2; (40) Dec. 11.
Towers and Anchorages of the Manhattan Bridge, New York.* (14) Dec. 12.
The Williamsburg Bridge across the East River at New York City.* (13) Dec. 17.
The Williamsburg Bridge and the Brooklyn Bridge.* (15) Dec. 18.
Moving the Passy Bridge, Paris. (14) Dec. 19.
The Main Span of the Williamsburg Bridge, across the East River, New York City.* (14) Serial beginning Dec. 19.
The Opening of the New East River Bridge, New York.* (19) Dec. 19.
A Concrete Arch Bridge with Bar and Stirrup Reinforcement.* (13) Dec. 31.
The Use of Scows and Sand Jacks in Moving and Lowering a 1 000-Ton Draw-Bridge over the Passaic River, at Newark, N. J.* Lincoln Bush. (13) Dec. 31; (20) Dec. 31; (40) Jan. 1; (15) Jan. 1.
A Proposed Plan for Rebuilding the Brooklyn Bridge.* (13) Jan. 7.
Pivot Pier Caisson and Operating Machinery for a Heavy Swing Bridge.* (13) Jan. 7.
Steel Concrete Abutments and Solid Floors for Railroad Bridges. A. O. Cunningham, M. Am. Soc. C. E. (15) Jan. 8.

Electrical.

The Measurement of Electrical Conductivity.* Rollo Appleyard, Assoc. M. Inst. C. E. (63) Vol. 154.
The Measurement of Power in Alternating Circuits.* Patrick Hamilton, Assoc. M. Inst. C. E. (63) Vol. 154.
Switchboard Construction for Isolated Electric Plants.* (64) Dec.
Electrical Development in Siberia.* L. Lodian. (64) Dec.
Testing Electric Generators by Air Calorimetry.* (11) Dec. 4; (62) Dec. 31.
Speed Variation of Continuous-Current Motors by Shunt Control. H. M. Hobart. (26) Dec. 4.
Stokers (for electricity generating stations). Albert Gay. (Paper read before the Soc. of Engrs.) (22) Dec. 4; (73) Dec. 11.
Street Lighting in Berlin: A Comparison between Electric Arc Lights and High-Pressure Gas Burners.* (Tr. of Paper read before the German Assoc. of Gas and Water Engrs. (66) Dec. 8.
The New Electricity Works at Exeter.* (73) Dec. 11.
Durban (S. Africa) Electric Light and Tramways.* (26) Serial beginning Dec. 11.
The Slow Registration of Rapid Phenomena by Strobographic Methods: "The Ondographe" and the "Puissancegraphe" (Wave-Recorder and Power Recorder).* E. Hospitalier. (Paper read before the Inst. of Elec. Engrs.). (73) Dec. 11.
The Testing of Electric Generators by Air Calorimetry. Richard Threlfall. (Abstract of Paper read before the Inst. of Elec. Engrs.) (26) Dec. 11.
Notes on Engine Driving in Electric Light Stations. F. T. Callis. (26) Serial beginning Dec. 11.
European Single-Phase Railway Motor.* (17) Dec. 12.
Grouping of Cells to Obtain Maximum Current. K. E. Guthe. (27) Dec. 12.
Motor-Driven Machinery.* Frank B. Kleinhans. (27) Dec. 12.
New Integrating Wattmeter for Alternating Current Circuits.* (27) Dec. 12.
The Reid Fuel Gas Battery.* (27) Dec. 12.
Recent Extensions of the Bradford Corporation Electrical Undertakings.* (26) Serial beginning Dec. 18.
The Stone Wireless Telegraph System.* Louis Duncan. (73) Dec. 18.
Producing High Tensions by Means of Alternating Current. (19) Dec. 19.
Physical Equipment of American Central Stations. (27) Dec. 19.
Electrically-Driven Shops. (Report of Committee to Master Mechanics' Assoc.) (18) Serial beginning Dec. 19.
Conductivity of Mercury Vapor.* Peter Cooper Hewitt. (27) Dec. 19.
German Gas Engine Power Stations.* Frank C. Perkins. (27) Dec. 19.
Switch Construction.* N. C. Woodfin. (26) Dec. 25.
Electrical Equipment of the Edison Portland Cement Company.* (27) Dec. 26.
The Berlin Printing-Telegraph Central Station.* Alfred Gradenwitz. (46) Dec 26.
Recent Electrical Researches by Berthelot. (19) Dec. 26.
Measurements of Electric Currents on Gas and Water Pipes in Geneva, Switzerland. (13) Dec. 31.
The "U. S." Secondary or Storage Batteries.* (21) Jan.
Electricity Direct from Fuel.* (64) Jan.
A Differential Duplex Telegraph System.* (73) Jan. 1.

* Illustrated.

Electrical—(Continued.)

High-Tension Continuous-Current Power Transmission at 20 000 Volts.* (73) Jan. 1.
A Wave Meter.* Johannes Dönitz. (From the *Elektrotechnische Zeitschrift.*) (73) Jan. 1.
Experiments on Eddy Currents.* W. M. Thornton. (Paper read before the Inst. of Elec. Engrs.) (73) Serial beginning Jan. 1.
Selection and Installation of High-Tension Switching Apparatus. L. L. Elden. (Paper read before a Convention of the Assoc. of Edison Illuminating Companies.) (73) Jan. 1.
Messrs. W. T. Glover and Co.'s Cable Works, Manchester.* (11) Jan. 1.
Ferranti A. C. Integrating Wattmeter.* (26) Jan. 1; (73) Jan. 1.
Christchurch Electricity Works.* (26) Jan. 1.
A New Electric Crane.* (26) Jan. 1.
On the Distribution of Light from Incandescent Lamps.* Lancelot W. Wild, A. M. I. E. E. (26) Jan. 1.
New Two-Rate Meter.* E. S. Shoults. (26) Jan. 1.
Water Power Electrical Generating Plant at Riva, Tyrol.* (27) Jan. 2.
Wireless Telegraph Theory.* (27) Jan. 2.
German Three-Phase Transformers.* (27) Jan. 2.
The Government Printing Office: The Electrical Equipment of the Largest Printing Office in the World.* (27) Serial beginning Jan. 2.
Testing Large Alternators.* W. E. Burnand. (27) Jan. 2.
Electrical Plant of the Lackawanna Steel Company.* (27) Jan. 2.
Protection of Electrical Apparatus from Lightning and Other Destructive High Potentials. Howard R. Sargent. (27) Jan. 2.
A New Line of Electric Traveling Cranes.* (20) Jan. 7.
New Types of Voltage Regulators for Generators.* (27) Jan. 9.
A Combined Steam and Water-Power Central Station at Richmond.* (27) Jan. 9.
The Design of Motor Starting Rheostats. Arthur H. Ford. (27) Jan. 9.
Régulation des Moteurs Appliqués à la Commande des Machines Dynamo-Électriques. R. V. Picou. (32) Oct.
Commande des Ascenseurs Électriques par Boutons-Contacts, Système Siemens-Schückert.* L. Ramakers. (33) Dec. 19.

Marine.

The Stone-Lloyd Bulkhead Door.* (12) Dec. 4.
The U. S. Steel Floating Dry-Dock for Cavite, Philippine Islands.* J. S. Shultz. (13) Dec. 10.
Screw Propulsion for Warships. (12) Dec. 11.
The Tyne General Ferry Co.'s Twin Screw Passenger Steamer *Mona*.* (11) Dec. 18.
One-Hundred-Ton Steel Floating Crane.* Jos. S. Shultz. (14) Dec. 19.
A Sectional Steamer for Our Colonial Possessions.* (46) Dec. 19.
The Launch of the New Transatlantic Liner *Baltic*.* Harold J. Shepstone. (46) Dec. 19.
Naval Boilers. (11) Dec. 25.
The Lake Submarine Torpedo Boat *Protector*.* (46) Dec. 26.
A Study of the Lake Submarine Torpedo Boat *Protector*.* John Halligan, Jr. (19) Serial beginning Dec. 26.
Shipbuilding and Marine Engineering, 1903. (11) Serial beginning Jan. 1.
System of Lighting H. M. Ships. (26) Jan. 1.
Les Navires Porte-Trains Danois.* A. Abraham. (36) Dec. 25.

Mechanical.

Description of the Duddingston Shale-Mines and the Niddrie Castle Crude-Oil Works.* J. Balfour Sneddon. (59) Vol. 26, Pt. 1.
The Policy of Gas Enrichment. Arthur Graham Glasgow, M. Inst. C. E. (8) Oct.
Heat Economy of the Steam Engine. (8) Oct.
Gas.* (Description of manufacture of Coal and Water Gas.) Thomas D. Miller. (Paper read before the Louisiana Eng. Soc.) (1) Oct.
Mond Gas-Driven Rolling Mills and Power Plant at the Works of Messrs. Monks, Hall & Company, Ltd., Warrington.* (22) Nov. 27.
The Transmission of Power by Ropes. Edwin Kenyon. (Abstract of Paper read before the Staffordshire Iron and Steel Inst.) (22) Nov. 27.
Diagram for Adiabatic Expansion of Steam.* Sven S. Ekman. (64) Dec.
The Use of Superheated Steam.* Storm Bull. (4) Dec.
Portland Cement Manufacture. Edwin C. Eckel. (60) Serial beginning Dec.
Low Pressure Hot Water Heating on the Reck Patent Circulator System.* C. Ingham Haden. (Paper read before the British Inst. of Heating and Ventilating Engrs.) (70) Dec.
Blast Furnace Gas Engines at the Lackawanna Steel Company's Plant.* (64) Dec.
Saturated Air Condensers.* (64) Dec.
Theory of the Cooling Tower. H. L. Nachman. (64) Dec.
Steam Turbines in Europe.* Emile Guarini. (64) Dec.
The Development of the Outside Spring Indicator.* Robert Grimshaw. (64) Dec.
The Jennison Water Cooler Tower.* (64) Dec.
Regularity of Firing.* J. W. Parker. (64) Dec.

* Illustrated.

Mechanical—(Continued).

Stokers (for electricity generating stations). Albert Gay. (Paper read before the Soc. of Engrs.) (22) Dec. 4; (73) Dec. 11.
A New Mechanism. (A four-piece skew linkwork.) G. T. Bennett. (11) Dec. 4; (62) Jan. 7.
Heavy Turret Lathe.* (11) Dec. 4.
The Hyatt Flexible Roller Bearing.* (22) Dec. 4.
Steam Autocar Notes: Small Steam Engines.* J. S. V. Bickford. (12) Dec. 4.
The Pelton Wheel for Rolling Mills.* (12) Dec. 4.
Notes on the Design of Vertical Boilers.* (47) Serial beginning Dec. 5.
The Bottom of a Green Sand Mould. Thomas D. West. (Paper read before the New England Foundrymen's Assoc.) (47) Dec 5.
Recent Developments in the Construction and Working of Gas-Engines. D. S. Capper, M. Inst. C. E. (Paper read before the Junior Inst. of Engrs.) (66) Dec. 8; (24) Serial beginning Jan. 11; (11) Dec. 18; (47) Serial beginning Jan. 2.
Street Lighting in Berlin: A Comparison between Electric Arc Lights and High-Pressure Gas-Burners. (Tr. of Paper read before the German Assoc. of Gas and Water Engrs.) (66) Dec. 8.
Economy in Mill Water.* Jesse Scobey (16) Dec. 10.
Power and Machinery at the St. Louis World's Fair.* (20) Dec. 10.
Pierson's "Suction" Gas Producer.* (62) Dec. 10.
Notes on the Design of Rolls.* Emil Kirchberg. (From *Stahl und Eisen.*) (20) Dec. 10.
The Westinghouse Blowing Engine.* (11) Dec. 11.
A Winding Engine Problem.* (12) Dec. 11.
Air Lift Pumps.* (12) Dec. 11.
Reciprocating Machine Tools.* (12) Dec. 11.
New Gas-Producing Plants.* (12) Dec. 11.
Davy's Automatic Valve Gear.* (47) Dec. 12.
Cost of Production of Power from Fuel. T. L. Miller, M. Inst. C. E. (47) Dec. 12.
Condensing Plant for High Vacuum with Limited Water Supply. W. H. Roy. (Paper read before the Manchester Assoc. of Engrs.) (47) Serial beginning Dec. 12.
The Manufacture of Steel Rails.* (19) Dec. 12.
Manufacture of Gun Steel and Armor Plate.* (19) Dec. 12.
Manufacture of Bridge and Building Structural Shapes.* (19) Dec. 12.
Manufacture of Steel Pipe.* (19) Dec. 12.
Steel Wire and Nail Making.* (19) Dec. 12.
Chain Making.* (19) Dec. 12.
Power Equipment in a Bottle Making Plant.* R. M. Hopkins. (14) Dec. 12.
Rules for the Specification of the Ironwork of Gasholders.—German Standards. (24) Serial beginning Dec. 14.
Lassiter Bolt-Turning Machine.* (62) Dec. 17.
Asphalt Mining and Refining in the Indian Territory.* W. R. Crane. (16) Dec. 17.
The Cruse Controllable Superheater.* (26) Dec. 18.
New Forms of the Steam Turbine. Robert H. Smith. (12) Serial beginning Dec. 18.
Electrically-Driven Well Pumps.* (12) Dec. 18.
Power Plant with Mechanical Draught.* (11) Serial beginning Dec. 18.
Military Tractor.* (12) Dec. 18; (11) Dec. 18.
Developments in Automobile Construction.* Thomas Clarkson, M. I. Mech. E., Assoc. M. Inst. C. E. (Paper read before the British Assoc. for the Advancement of Science.) (11) Dec. 18.
Electrically-Driven Shops. (Report of Committee to Master Mechanics' Assoc.) (18) Serial beginning Dec. 19.
Test of Turbines for the Cleveland, Elyria & Western Railway. (17) Dec. 19.
A New Smoke Consuming Furnace.* (17) Dec. 19.
A Direct-Acting Steam Shovel.* (18) Dec. 19; (40) Dec. 18.
The Top of a Green Sand Mould. Thos. D. West. (47) Dec. 19.
The Mechanical Plant of the Broadway-Maiden Lane Building, New York.* (14) Dec. 19.
One-Hundred-Ton Steel Floating Crane.* Jos. S. Shultz. (14) Dec. 19.
The Power Plants of the St. Louis World's Fair. (14) Dec. 19.
Edison Portland Cement Company: Plant at New Village, N. J.* (20) Dec. 24; (27) Dec. 26; (14) Dec. 26; (13) Dec. 24; (67) Dec.
The New Flues and Stack at Anaconda.* (16) Dec. 24.
The Practical Working of Trench Excavating Machinery.* Ernest McCullough. (13) Dec. 24.
Condensing Plant for High Vacuum. (62) Dec. 24.
Smoke Prevention. W. H. Bryan. (Abstract of Address delivered before the engineering students of Purdue Univ.) (15) Dec. 25; (62) Jan. 7.
Some Recent Examples of German Crane Construction.* (22) Dec. 25.
The Westinghouse Foundry at Trafford City.* (15) Dec. 25.
Thread-Milling Machine. (11) Dec. 25.
Air Motors and Air Hammers. Max. H. Wickhurst. (18) Dec. 26.
Heating Costs of Various Systems. J. Byers Holbrook. (14) Dec. 26.
The Efficiency of Centrifugal Pumps. (14) Dec. 26.
Improvements in Valve Gears.* John Riekie. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Dec. 26.

---

* Illustrated.

Mechanical—(Continued).

Westinghouse Steam Turbine.* (47) Dec. 26.
The Renard Dynamometric Fan for Measuring the Power of Gasoline Motors.* (19) Dec. 26.
Peat Coal by Electrical Process. (46) Dec. 26.
A Pneumatic Rail Unloader.* (46) Dec. 26.
Thorneycroft's Starting Device for Explosion Motors.* (47) Dec. 26.
A Combined Coal and Water Gas Plant.* (66) Dec. 29.
The Ball Crank Pin Grinder.* (20) Dec. 31.
Key Seat Milling and Routing Machine.* (20) Dec. 31.
The Bullard 42-inch Boring and Turning Mill.* (20) Dec. 31.
American Tests of Rapid Cutting Tool Steels. (20) Dec. 31.
Blast Furnace Gas as a Source of Power.* (64) Jan.
Hydraulic Power in Foundry and Machine Shop.* Joseph Horner. (10) Jan.
Superheated Steam for Steam Engines.* Bryan Donkin. (10) Jan.
The Condenser Plant at Glasgow Electric Power Station.* (64) Jan.
Starting Gas Engines.* W. S. Ferry. (64) Jan.
A Novel Design of Electrically-Driven Milling Machines.* (25) Jan.
The Kilgore Direct-Acting Steam Shovel.* (25) Jan.; (13) Dec. 17; (15) Dec. 18.
Acme Gas, a New Fuel.* (25) Jan.
Cutting Speeds and Feeds with the New Tool Steels. Oberlin Smith. (9) Jan.
European High-Power Gas Engines of Recent Design. Frank C. Perkins. (41) Jan.
The Allis-Chalmers Company's New Plant at West Allis.* (41) Jan.
The Hot-Water Meter for Boiler-Evaporative Tests.* John A. Drew. (41) Jan.
The Mechanics of a Barrier-Pole.* (21) Jan.
Sugden's Combined Stop and Isolating Valve.* (11) Jan. 1.
Preliminary Experiments on Air Friction.* W. Odell. (Paper read before the British Assoc. for the Advancement of Science.) (11) Jan. 1.
Machines and Tools Employed for Die-Cutting.* Joseph Horner. (11) Serial beginning Jan. 1.
Heat Transference through Boiler-Plates.* (11) Jan. 1.
Constant Belt Speed Milling Machine. (18) Jan. 2; (41) Jan.
The Inspection and Care of Steam Boilers. (47) Serial beginning Jan. 2.
Types of Gas Producers.* A. Humboldt Sexton. (47) Serial beginning Jan. 2.
Conveyors in Modern British Power Houses.* Arch. J. S. B. Little. (17) Jan. 2.
The Clairton Twenty-eight-Inch Three-High Steel Billet Mill.* (14) Jan. 2.
High Power Westinghouse-Parsons Steam Turbines.* (14) Jan. 2; (27) Jan. 2.
Notes on Gaseous Firing.* J. F. Smith. (Paper read before the Yorkshire Junior Gas Assoc.) (24) Jan. 4; (66) Dec. 15.
Heating and Ventilating of Foundries and Machine Shops. W. H. Carrier. (Paper read before the Amer. Foundrymen's Assoc.) (24) Jan. 4.
"A. W." Rapid Cutting Tool Steel. (62) Jan. 7.
The Wieland Pipe Threading and Cutting Machine.* (20) Jan. 7.
Modernization in Engine Building. The New Plant of the Hooven-Owens-Reutschler Company.* (20) Jan. 7.
Cincinnati Electrically Driven Milling Machine.* (20) Jan. 7.
Whiting Punching and Coping Machine.* (20) Jan. 7.
Rapid Machining of Crank Shafts.* (20) Serial beginning Jan. 7.
Central Condensing Systems.* Louis R. Alberger. (20) Jan. 7.
Problems in the Designing of Large Steam Units. (20) Jan. 7.
Works of the Lackawanna Steel Company, Buffalo, N. Y.* (20) Jan. 7.
The Almendares Portland Cement Works, Cuba.* (14) Jan. 9.
5000-K. W. Westinghouse-Parsons Turbo Units.* (17) Jan. 9.
Some High Power Gas Burners.* W. H. Birchmore. (24) Jan. 11.
A Rapid Method for the Determination of Sulphur in Coal and Coke. J. D. Pennock and D. A. Morton. (24) Jan. 11.
Calcul du Benefice du à la Surchauffe dans les Machines Imparfaites. M. Delaporte. (37) Nov. 30.
Les Turbines à Vapeur et l'Avenir des Moteurs Thermiques.* M. Stodola. (Tr. by M. Barsky from the *Zeitschrift des Vereines Deutscher Ingenieure.*) (37) Serial beginning Nov. 30.
Régulateur pour Turbines Lombard.* (37) Nov. 30.
Les Outils Rapides.* J. T. Nicolson. (37) Nov. 30.
Note Relative à la Transmission de la Chaleur à Travers les Parois d'un Local Chauffé. E. Mathieu. (30) Dec.
Rampe Mobile Électrique entre la Plage et la Ville Biarritz.* René Weil. (33) Dec. 12.
Le Train Automobile à Propulsion Continue du Colonel Ch. Renard.* G. Espitallier. (33) Dec. 19.

Metallurgical.

The Analysis of High Speed Steels. (62) Dec. 10; (12) Dec. 11.
A New Process for Avoiding Piping in Steel Ingots.* (22) Dec. 18.
The Freid Gravity Dry-Process Separator.* Douglas McLean. (16) Dec. 24.
Testing Ores by Vanning.* Richard Pearce. (16) Dec. 24.
The New Flues and Stack at Anaconda.* (16) Dec. 24.
Some Neglected Points in Furnace Construction.* (62) Dec. 31.

* Illustrated.

Metallurgical—(Continued).

The Effect of Impurities on Commercial Copper. Ernest A. Lewis. (62) Dec. 31.
Milling of Silver Ores at Pachuca. Henry F. Collins. (Abstract of Paper read before the Inst. of Min. and Metal.) (16) Dec. 31.
The Canadian Copper Company's Plant at Copper Cliff.* (16) Dec. 31.
Brazing Cast Iron.* (64) Jan.
Mechanical and Metallurgical Applications of Aluminothermics.* Emile Guarini. (9) Jan.
Some Practical Hints on the Manufacture of Open Hearth Basic Steel. A. G. Wilson. (Paper read before the West of Scotland Iron and Steel Inst.) (62) Jan. 7.

Military.

Manufacture of Gun Steel and Armor Plate.* (19) Dec. 12.
Military Tractor.* (12) Dec. 18; (11) Dec. 18.
Stability Tests for Nitrocellulose and Nitrocellulose Powders.* Albert P. Sy. (19) Serial beginning Jan. 2.

Mining.

Mine Dams.* Alexander Faulds. (59) Vol. 26, Pt. 1.
Safety Appliances for the Prevention of Overwinding.* H. Kuss. (From *Annales des Mines.*) (57) Serial beginning Dec. 4; Abstract (22) Dec. 11.
Winding Plant for the Oliver Iron Mining Company, at Ely, Minn. (22) Dec. 4.
Asphalt Mining and Refining in the Indian Territory.* W. R. Crane. (16) Dec. 17.
The Mineville Magnetite Mines: Recent Improvements of the Mining and Separating Plant of Witherbee, Sherman & Co., Port Henry, N. Y.* (20) Dec. 17.
A Miner's Safety-Lamp Tester.* (12) Dec. 18; (22) Dec. 18.
Blosfield's Safety Brake for Winding Engines.* (22) Dec. 18.
Improved Mining Appliances in Belgium Collieries.* A. Marcette. (From *Annales des Mines de Belgique.*) (57) Dec. 24.
The Limits and Possibilities of Deep Mining.* E. H. Roberton. (9) Jan.
The Treadwell Group of Mines, Douglas Island, Alaska.* Robert A. Kinzie. (45) Jan.
Deep Alluvial Mining in New South Wales, Australia.* D. H. Browne. (Paper read before the Australasian Inst. of Min. Engrs.) (45) Jan.
An Improved Tunneling Shield.* (14) Jan. 2.
Applications de l'Énergie Électrique dans les Mines d'Europe.* F. Desquiens. (36) Dec. 25.
Appareils de Sécurité pour Plans Inclinés.* H. Schmerber. (33) Serial beginning Dec. 26.

Miscellaneous.

Some Unsolved Problems in Engineering. W. H. Maw, M. Inst. C. E. (63) Vol. 154.
Theory of Units. Antonio Llano. (8) Oct.
Cost of Earth Excavation by Steam Shovel. Daniel J. Hauer. (13) Dec. 31.
The Homes of the Great Engineering Societies.* Henry Harrison Suplee. (9) Jan.

Municipal.

Street Lighting in Berlin: A Comparison between Electric Arc Lights and High-Pressure Gas Burners.* (Tr. of Paper read before the German Assoc. of Gas and Water Engrs.) (66) Dec. 8.
Use of Medina Sandstone for Pavements in Brooklyn, New York City. C. D. Pollock. (14) Dec. 26.
Criticisms of Asphalt Paving Estimates at Detroit, Mich. W. F. Raymond. (60) Jan.
Raising the Grade of Galveston * (15) Jan. 1.

Railroad.

Notes on Railroad Surveying. Charles John Albrecht, M. Inst. C. E. (63) Vol. 154.
American Locomotive Practice.* Percy John Cowan, Assoc. M. Inst. C. E. (63) Vol. 154.
The Use of a Logarithmic Scale in Plotting Curves.* Russell Scott Scholefield, Assoc. M. Inst. C. E. (63) Vol. 154.
Staybolts. (For Locomotive Boilers.) H. A. Fergusson. (61) Nov. 17; Abstract (47) Dec. 12.
Train Pipe Leakage. C. C. Farmer. (61) Nov. 17.
Suburban Carriages: Illinois Central Railroad.* (21) Dec.
Four Coupled "Atlantic" Express Engines: Great Central Railway.* (21) Dec.
8-Coupled Tank Engine for Suburban Traffic: Great Northern Railway.* (21) Dec.
Six-Coupled Bogie Express Engines: Glasgow and South Western Railway.* (21) Dec.
The Westinghouse Electro-Gas Signal.* (11) Dec. 4; (62) Dec. 31.
The French Locomotive for the Great Western Railway.* Charles Rous-Marten. (12) Dec. 4.
Six-Wheels Coupled Express Locomotive—Chemin de Fer de l'Est.* (12) Dec. 11.
Wabash Steel Concrete Construction.* (40) Dec. 11.
Driving Last Spike on the Ogden-Lucin Cutoff.* (40) Dec. 11.
The First Consolidation Locomotive for Great Britain.* (40) Dec. 11.
New Santa Fé Freight Houses at Kansas City.* (15) Dec. 11.
Signaling at Phillipsburg and Easton.* (15) Dec. 11.

* Illustrated.

Railroad—(Continued).

Ogden-Lucin Cut-Off.* (15) Dec. 11.
Terminal Passenger Station for the Wabash R. R. at Pittsburg.* (18) Dec. 12.
The Central London Railway. (47) Dec. 12.
Experiments with a New Type of Compound Locomotive in Italy.* (19) Dec. 12.
The Manufacture of Steel Rails.* (19) Dec. 12.
The Cost of Concrete Tunnel Lining and of Tunnel Excavation.* Geo. W. Lee, Jun. Am. Soc. C. E. (13) Dec. 17.
Stone Ballast. E. A. Hermann, M. Am. Soc. C. E. (13) Dec. 17.
Hall Electro-Gas Normal Danger Signals on the Union Pacific.* (15) Dec. 18.
M'Kees Rocks Shops of the Pittsburg & Lake Erie.* (40) Dec. 18.
Two New Railroads in Alaska.* (15) Dec. 18.
New Passenger Equipment of the Chicago Great Western.* (15) Dec. 18.
New Cafe Parlor Car, Chicago Great Western Ry.* (18) Dec. 19; (40) Dec. 18; (39) Jan.
Tunnel Work of the Pennsylvania Entrance into New York.* (18) Dec. 19.
Locomotive Testing at the St. Louis Exposition. (18) Dec. 19.
The Design of Locomotive Front Ends. W. F. M. Goss. (47) Serial beginning Dec. 19.
A Track Circuit Block Signal for Electric Railways.* (13) Dec. 24; (40) Dec. 11.
Wabash Atlantic-Type Locomotives.* (15) Dec. 25.
The "Young System" of Automatic Block Signals.* (15) Dec. 25.
The Philadelphia & Reading Norristown Connection.* E. Chamberlain. (40) Dec. 25.
The Locomotive Boiler—Its Growth and Needs.* G. R. Henderson. (40) Dec. 25.
The New Lake Shore Consolidation Engines.* (40) Dec. 25.
Heavy Tank Locomotive for the Great Northern Railway.* (11) Dec. 25.
Automatic Block Signals for Electric Railways.* (18) Dec. 26.
The First British Steam Railway to Adopt Electrical Working. (46) Dec. 26.
The Newark Improvements of the Lackawanna Railroad.* (14) Serial beginning Dec. 26.
Car Heating by Steam Mixed with Air; Eastern Railway of France.* (13) Dec. 31.
The New Southern Pacific Passenger Station at San Antonio, Tex.* John D. Isaacs, M. Am. Soc. C. E. (13) Dec. 31; (15) Dec. 18.
The Care of Locomotive Boilers. M. E. Wells. (Abstract of Paper read before the Pacific Coast Ry. Club.) (21) Jan.
Ten-Wheeled Express Passenger Engines: Great Central Railway.* (21) Jan.
The Brill 27 G. Truck.* (21) Jan.
10 or 12-Ton Private Owners' Wagons.* (21) Jan.
Rail Bonds. W. E. Harrington. (3) Serial beginning Jan.
Heavy New Freight Locomotive: New York Central & Hudson River Railroad: 2—8—0 Type.* (25) Jan.
The Pennsylvania Railroad Locomotive Testing Plant for the St. Louis Exposition. (25) Jan.
The Marienfelde-Zossen High-Speed Electric-Railway Trials.* Alfred Gradenwitz. (9) Jan.
Coal and Water Tests of Freight Locomotives.—A., T. & S. F. Ry. (39) Jan.
Freight Locomotive—Chesapeake & Ohio Railway.* (39) Jan.
Locomotive Frame Deflections.* (25) Jan.
Heavy Freight Locomotives: Lake Shore & Michigan Southern Railway: 2-8-0 Type.* (25) Jan.; (39) Jan.
The Chamonix Electric Railway.* Archibald Wilson. (10) Jan.
The Railroad around the Falls of the Madeira River, Brazil.* O. F. Nichols. (15) Jan. 1.
50-Ton Steel Underframe Box Car.* (15) Jan. 1.
Electrification of the Liverpool-Southport Line.* (12) Jan. 1.
Chicago & Alton New Atlantic Locomotive.* (40) Jan. 1.
Alternating-Current Signals on Electric Roads.* (27) Jan. 2.
Heavy Consolidation Locomotive, Lake Shore & Michigan Southern Ry. (18) Jan. 2.
Reconstruction of the Lackawanna Tracks through Newark.* (46) Jan. 2.
An Improved Tunneling Shield.* (14) Jan. 2.
Electrical Equipment of the North Shore Railroad from San Francisco to San Rafael.* (17) Serial beginning Jan. 2.
The Development of Railroad Braking. R. A. Parke. (17) Jan. 2.
High Potential Oil Switches.* (17) Jan. 2.
Relocation of the Central Massachusetts Railroad around the Wachusett Reservoir.* (14) Jan. 2.
Brakes and Sand. Edward C. Boynton. (17) Jan. 2.
A Railway Ditching Machine.* (13) Jan. 7.
New York, Ontario & Western Box Car.* (15) Jan. 8.
The Calculation of the Stresses and the Practical Design of Structures of Steel Concrete.* Walter W. Colpitts. (40) Jan. 8.
All-Electric Interlocking.* (40) Jan. 8.
Superheated Steam Freight Locomotive—Saxony State Railways.* Charles R. King. (13) Jan. 8.
Turbo-Generator Units for Pennsylvania R. R. Tunnel.* (18) Jan. 9.
The Adoption of Direct Current Traction on the New York Central Railroad System. (27) Jan. 9.

* Illustrated.

Railroad—(Continued).

100,000-Lbs. Capacity Coal Car, C., M. & St. P. Ry.* (18) Jan. 9.
Electric Interlocking for the Texas & Pacific Ry., at Texarkana.* (18) Jan. 9.
Types Récents de Voitures des Chemins de Fer et Tramways Hongrois.* A. Morizot. (34) Dec.
Les Heurtoirs Hydrauliques de la Gare d'Anvers G. C.: Système Hoppe.* L. Cosyn (34) Dec.
Système Nouveau pour Revêtement de Talus de Tranchées de Chemins de Fer, Routes, etc. M. A. Casse. (30) Dec.
Note sur les Appareils Électriques pour la Commande des Aiguilles et des Signaux (Système Ducousso et Rodary).* M. Rodary. (38) Dec.
Frein Automatique a Air Comprimé: Système Lipkowski. F. Barbier.* (33) Dec. 5.
Les Locomotives pour Voie Etroite avec Fortes Rampes et Courbes de Faible Rayon.* R. Bonnin. (36) Dec. 10.
Construction de Tunnels en Terrains Immergés.* (33) Dec. 26.

Railroad, Street.

Tramroads in Connection with Street Tramways.* Harry Ernest Prescott, M. Inst. C. E. (63) Vol. 154.
The Effect of Multiple Control on the Traction Problem of Pittsburg. N. W. Storer. (58) Nov.
Durban (S. Africa) Electric Light and Tramways.* (26) Serial beginning Dec. 11.
Interurban Electric Traction Systems—Alternating Versus Direct-Current. Paul M. Lincoln. (27) Dec. 12.
Economies Introduced by the Use of the Automotoneer. (17) Dec. 12.
Electric Heating of Third Rails for Sleet Removal.* (17) Dec. 12.
European Single-Phase Railway Motor.* (17) Dec. 12.
Working Results on the City and South London Railway.* (73) Serial beginning Dec. 18.
The Winter-Eichberg Single-Phase Railway System.* (27) Dec. 19.
Improvements on a Kentucky System.* (17) Dec. 19.
Alternating Motors for Railway Service. Louis Bell. (17) Dec. 19.
The Rolling Stock of the Great Northern and City Railway.* (12) Dec. 25.
The City and South London Railway. P. V. McMahon. (Abstract of Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Dec. 26; (26) Serial beginning Dec. 25.
Electric Traction by Monophase Current.* Emile Guarini. (19) Dec. 26.
An Improved Method of Subaqueous Construction at the Harlem River Crossing of the New York Rapid Transit Railroad.* (14) Dec. 26.
Application of Single-Phase Alternating Current for Traction and Railway Service. B. G. Lamme. (27) Dec. 26; (17) Dec. 26.
New Interurban Railway in Switzerland.* (17) Dec. 26.
Repair Shop Practice on the Camden & Suburban Road.* (17) Dec. 26.
The Evolution of the Electric Railway Motor. S. T. Dodd. (Abstract of Paper read before the New York Elec. Assoc.) (17) Dec. 26.
Alternating Current for Signaling on Interurban Electric Railways.* (17) Dec. 26.
Tram-Rail Joints.* (21) Jan.
A New System for a Track Circuit.* (40) Jan. 1.
Electric Traction with Alternating Currents. A. C. Eborall. (Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Jan. 2; (26) Serial beginning Jan. 1; (73) Serial beginning Dec. 18.
Arnold Electro-Pneumatic Railway System—Lansing, St. Johns & St. Louis Ry.* (18) Jan. 2; (15) Jan. 1; (40) Jan. 8.
Semi-Convertible Cars for the Public Service Corporation of New Jersey.* (17) Jan. 2.
The Arnold Electro-Pneumatic Railway System as Employed on the Lansing, St. Johns and St. Louis Railway.* Bion J. Arnold, M. Am. Inst. E. E. (27) Jan. 2; (19) Jan. 9; (17) Jan. 2; (13) Jan. 7.
The Jackson & Battle Creek Railway.* W. G. Fargo. (17) Jan. 2.
The Street Railway System of Richmond, Va.* (17) Jan. 2.
The Steam-Hydraulic Plant of the Virginia Passenger & Power Company, Richmond.* (14) Jan. 2.
Combination Snow-Plow and Freight Car.* (17) Jan. 9.
Inter-Urban Electric Traction Systems. (18) Serial beginning Jan. 9.
Controleur Électropneumatique: Système Westinghouse.* (33) Nov. 28.

Sanitary.

Inverted Syphons in the Sewerage System of Newton, Mass.* Irving T. Farnham. (60) Dec.
Plumbing in the Stable of Col. Daniel S. Lamont, New York.* (70) Dec.
Sewage Disposal in Iowa.* A. Marston. (4) Dec.
The Experimental Bacterial Treatment of London Sewage. Frank Clowes. (60) Dec.
A Comparison of Chemical and Septic Tank Systems as Preludes to Artificial Filtration. Douglas Archibald. (Abstract of Paper read before the British San. Inst.) (60) Dec.
The Typhoid Fever Epidemic at Butler, Pa.* George A. Soper, Assoc. M. Am. Soc. C. E. (13) Dec. 24.
The Farington Sewage Disposal Works. (14) Dec. 26.

---

* Illustrated.

Sanitary—(Continued).

The Septic Tank for the Treatment of Sewage at the Soldiers' Home near Santa Monica, Cal.* James D. Schuyler. (60) Jan.
The Sanitary Disposal of Municipal and Institutional Waste by Cremation.* W. F. Morse. (Abstract of Paper read before the Amer. Public Health Assoc.) (60) Jan.
Ventilation and Heating in the Penobscot County Court House, Bangor, Maine.* (14) Jan. 2.
Water Supply and Drainage Systems in the Lorraine Hotel, New York.* (14) Jan. 9.
Bains Populaires.* (36) Dec. 10.

Structural.

The Decay of Metals.* James Tayler Milton, M. Inst. C. E., and William James Larke. (63) Vol. 154.
Concrete-Metal Construction.* Emile Villet. (Paper read before the Technical Soc. of the Pacific Coast.) (1) Oct.
Portland Cement Manufacture. Edwin C. Eckel. (60) Serial beginning Dec.
Iron Roofs for Gas-Works.* Norton H. Humphrys, Assoc. M. Inst. C. E. (66) Dec. 8; (24) Dec. 28.
A Suspended Curved Double Stairway of Reinforced Concrete.* (14) Dec. 12.
The Concrete-Steel Stadium on the Athletic Field of Harvard University.* (14) Dec. 12.
Concrete-Steel Columns for Reinforcing an Old Building.* Keith O. Guthrie. (13) Dec. 17.
Raising a Brick Dwelling One Hundred and Sixty Feet.* (14) Dec. 19.
The New Flues and Stack at Anaconda.* (16) Dec. 24.
The New Worthington Hydraulic Works at Harrison, N. J.* (13) Dec. 31.
Structural Details of the Kuhn-Loeb Building, New York.* (14) Jan. 2.
The Effect on the Tensile Strength of Cement of Removing Briquettes from Water for Varying Lengths of Time before Breaking. J. L. Van Ornum, M. Am. Soc. C. E. (13) Jan. 7.
Underpinning a Corner Column on a Slender Pier.* (14) Jan. 9.
Fabrication du Ciment Portland Artificiel.* A. Morel. (33) Serial beginning Nov. 28.
Usine à Chaux Hydraulique et Ciment de Grappier, de la Société Anonyme des Chaux de Galeria (Corse).* J. Boero. (35) Dec.
Petites Maisons Jumelles, Rue Masset, à Vichy (Allier).* E. Rivoalen. (35) Dec.

Topographical.

The Use of a Logarithmic Scale in Plotting Curves.* Russell Scott Scholefield, Assoc. M. Inst. C. E. (63) Vol. 154.
Two Problems in Field Engineering.* Arnold Emch. (13) Dec. 31.

Water Supply.

Siphon for the Guernsey Water-Works.* Gerrard Hatfield Perryn, Assoc. M. Inst. C. E. (63) Vol. 154.
New Lanarkshire Middle-Ward District Water-Works.* William Archer Porter Tail. (63) Vol. 154.
Empirical Formulas for Finding the Maximum Discharges of Rivers. Robert Hunter Rhind, M. Inst. C. E. (63) Vol. 154.
Rainfall and Run-Off of New England, Atlantic Coast and Southwestern Colorado Streams. William O. Webber. (1) Nov.
How Cleveland is Checking Water Waste. (60) Dec.
A Gas Engine Pumping Station.* (64) Dec.
The Water-Works of Erie, Pa.* (60) Dec.
The Water Supply in the Blair Building, New York.* (70) Dec.
A New Disk Meter for Water Service.* (70) Dec.
The Kennicott Water Softener.* (11) Dec. 11.
Architectural Features of Masonry Dams.* (14) Dec. 12.
The New Water Supply Tunnel of Cleveland, Ohio. Charles Goffing. (14) Dec. 12.
Cofferdam for the 39th Street Pumping Station at Chicago.* (13) Dec. 17.
The Walden Pond Dam of the Lynn Water-Works.* George I. Leland. (14) Dec. 19.
The Storage of Flood Water. Henry Robinson, M. Inst. C. E. (Paper read before the British Assoc. of Water-Works Engrs.) (66) Dec. 22.
An Inquiry into the Working of Various Water-Softeners. C. E. Stromeyer, M. I. Mech. E., and W. B. Baron. (12) Serial beginning Dec. 25; (22) Dec. 25; (11) Dec. 25.
New Water Supply for Margate.* (12) Dec. 25.
The Mechanical Filter Plant for the Danville Water Company.* (14) Dec. 26.
A New Reservoir for the Hoylake and West Kirby Gas and Water Company. Alfred J. Jenkins, Assoc. M. Inst. C. E. (Abstract of Paper read before the British Assoc. of Water-Works Engrs.) (66) Dec. 29.
The Failures and the Possibilities of Water Filtration. Allen Hazen, M. Am. Soc. C. E. (13) Dec. 31.
The Cincinnati Water-Works Tunnel.* Paul G. Brown, M. W. Soc. C. E. (13) Dec. 31.
The Clarification of Ohio River Water at Cincinnati. Frank J. Kelley. (Paper read before the Central States Water-Works Assoc.) (60) Jan.
The Belmont Filtration Works.* John W. Hill. (3) Serial beginning Jan.
Water Supply and Drainage Systems in the Lorraine Hotel, New York.* (14) Jan. 9.

---

* Illustrated.

Topographical—(Continued).

The Conduit of the Jersey City Water Supply Company.* (14) Serial beginning Jan. 9.
The Filter Galleries for the Water-Works of Laredo, Texas. A. L. McLane. (14) Jan. 9.
Barrage en Terre de Tabeaud près de Jackson (Californie).* G. Richon. (33) Dec. 19.

Waterways.

The Protection Works of the Kaisar-i-Hind Bridge over the River Sutlej, near Ferozepur. Amyas Morse, M. Inst. C. E. (63) Vol. 154.
The Haskell Self-Registering Water Gauge.* G. A. M. Liljencrantz. (4) Dec.
Dredging Plant and Clyde Improvement.* (12) Dec. 18.
A New Station for the Rating of Current Meters by the U. S. Geological Survey, at Denver, Colorado.* M. C. Hinderlider. (14) Dec. 19.
The Solution of the Isthmian Canal Problem. Henry L. Abbot. (9) Jan.
Organization and Personnel in the Building of the Panama Canal. Fullerton L. Waldo. (9) Jan.
Raising the Grade of Galveston.* (13) Jan. 1.
Argentine Rivers.* E. L. Corthell, M. Am. Soc. C. E. (13) Jan. 7.
Electricity on the Miami and Erie Canal.* (46) Jan. 9.
Le Port d'Escale de Zeebrugge.* Charles Piens. (30) Dec.
Notice sur un Système de Revêtement en Dalles a Emboîtements pour la Consolidation des Talus des Digues des Canaux et Rivières et des Digues de Mer. J. Conard. (30) Dec.
Notice sur les Derniers Travaux Exécutés aux Ports de Gênes et de Venise.* G. B. Antonelli. (30) Dec.

AMERICAN SOC

OF

CIVIL ENGINEI

February, 1904.

PROCEEDINGS - VOL. XXX

Published at the House of the Society, 220 West Fifty-seventh
the Fourth Wednesday of each Month, except June a

Entered as Second-Class Matter at the New York City Post Office, I

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXX. No. 2.

FEBRUARY, 1904.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1904.

American Society of Civil Engineers.

OFFICERS FOR 1904.

President, CHARLES HERMANY.

Vice-Presidents.

Term expires January, 1905:
L. F. G. BOUSCAREN,
JAMES D. SCHUYLER.

Term expires January, 1906:
F. S. CURTIS,
S. L. F. DEYO.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1905:
RICHARD S. BUCK,
GEORGE H. PEGRAM,
WILLIAM J. WILGUS,
WILLIAM JACKSON,
EDMUND F. VAN HOESEN,
JAMES L. FRAZIER.

Term expires January, 1906:
ALFRED CRAVEN,
JOSEPH O. OSGOOD,
GEORGE S. DAVISON
E. C. LEWIS,
HUNTER McDONALD.
ELWOOD MEAD.

Term expires January, 1907:
CHARLES S. GOWEN,
NELSON P. LEWIS,
JOHN W. ELLIS,
GEORGE S. WEBSTER.
RALPH MODJESKI,
CHARLES D. MARX.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:
S. L. F. DEYO,
L. F. G. BOUSCAREN,
RICHARD S. BUCK,
WILLIAM J. WILGUS.
CHARLES S. GOWEN,

On Publications:
GEORGE H. PEGRAM,
ALFRED CRAVEN,
JOSEPH O. OSGOOD,
GEORGE S. DAVISON.
HUNTER McDONALD.

On Library:
NELSON P. LEWIS,
WILLIAM JACKSON,
E. C. LEWIS,
RALPH MODJESKI,
CHARLES WARREN HUNT

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, W. B. W. Howe, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, F. H. Lewis.

ON RAIL SECTIONS:—L. F. G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 588 Columbus.
CABLE ADDRESS, - - - - - "Ceas, New York."

Vol. XXX. FEBRUARY, 1904. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

FIFTY-FIRST ANNUAL MEETING.*

January 20th, 1904.—The meeting was called to order at 10.15 A. M.; President Alfred Noble in the chair; Charles Warren Hunt, Secretary; and present, also, about 300 members.

The reading of the minutes of the meeting of January 6th, 1904, was dispensed with.

* A full report of the Fifty-first Annual Meeting is printed on pages 51 to 93 of this number of *Proceedings*.

Messrs. A. W. Trotter, H. M. Rood and B. C. Collier were appointed tellers to canvass the Ballot for Officers for the ensuing year.

The Annual Report of the Board of Direction and the Annual Reports of the Secretary and of the Treasurer* for the year ending December 31st, 1903, were presented, and, on motion, duly seconded, accepted and placed on file.

The following were appointed members of the Nominating Committee for two years:

ALBERT CARR................	*Representing*	*District*	*No. 1.*
FREDERICK BROOKS	"	"	*No. 2,*
H. A. VAN ALSTYNE	"	"	*No. 3.*
H. R. LEONARD..............	"	"	*No. 4.*
JOSEPH B. DAVIS............	"	"	*No. 5.*
G. B. NICHOLSON	"	"	*No. 6.*
FRANKLIN RIFFLE............	"	"	*No. 7.*

A progress report† from the Special Committee on Uniform Tests of Cement was read by the Secretary.

On motion, duly seconded, the report was received, placed on file, and the Committee continued.

The Secretary reported that the Board of Direction had awarded the prizes for the year ending with the month of July, 1903, in accordance with the recommendations of the Committee appointed for that purpose, as follows:

That no award of The Norman Medal be made;

That The Thomas Fitch Rowland Prize be awarded to Paper No. 954, "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E.;

That The Collingwood Prize for Juniors be awarded to Paper No. 939, "The Footbridge for Building the Cables of the New East River Bridge," by Isaac Harby,‡ Jun. Am. Soc. C. E.

The Secretary presented a special report as to the Engineering Congress and the Society Convention.§

On motion, duly seconded, the report was received and ordered placed on file.

The Secretary presented a special report‖ from the Board of Direction in the matter of the appointment of a Special Committee on "Concrete and Steel-Concrete."

On motion, duly seconded, it was carried by a two-thirds vote to refer the matter to the membership for letter-ballot.

The Secretary presented the special report of the Board of Direc-

* The Annual Reports of the Board of Direction, the Secretary and the Treasurer, may be found on pages 7 to 16 of the *Proceedings* for January, 1904 (Vol. XXX).

† See page 55.

‡ Mr. Harby has since been elected an Associate Member.

§ See page 57.

‖ See page 58.

tion on the action of the Society on the proposed Union Engineering Building.*

The President made a statement in reference to a subsequent interview with Mr. Andrew Carnegie.†

The Secretary read a letter‡ from William D. Pickett, M. Am. Soc. C. E., in reference to the proposed Union Engineering Building.

The adoption of the following resolutions, offered by the Board of Direction, was moved, seconded and carried:

(1) *Resolved*, That the Board of Direction be instructed to issue a letter-ballot, to be canvassed at the Meeting of the Society, March 2d, 1904, on the question whether this Society shall become one of the Constituent Societies in the occupancy and control of the proposed Union Engineering Building, under the terms outlined by the Joint Conference Committee.

(2) *Resolved*, That should a majority of the votes cast be favorable, the Board is authorized to proceed in the matter, provided the exemption from taxation of the proposed building is assured, and the interests of the Society are otherwise fully safe-guarded.

The Secretary presented the report§ of the tellers appointed to canvass the Ballot for Officers for the ensuing year.

The President announced the election of the following officers:

President, to serve one year:

CHARLES HERMANY, Louisville, Ky.

Vice-Presidents, to serve two years:

F. S. CURTIS, Boston, Mass.
S. L. F. DEYO, New York City.

Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

Directors, to serve three years:

District No. 1.—CHARLES S. GOWEN, Ossining, N. Y.
District No. 1.—N. P. LEWIS, New York City.
District No. 2.—JOHN W. ELLIS, Woonsocket, R. I.
District No. 4.—GEORGE S. WEBSTER, Philadelphia, Pa.
District No. 5.—RALPH MODJESKI, Chicago, Ill.
District No. 7.—CHARLES D. MARX, Stanford University, Cal.

Mr. Croes and Mr. Cartwright conducted Mr. Hermany, the President-elect, to the chair.

Mr. Hermany addressed the meeting briefly.

Adjourned.

---

* See page 99.
† See page 60.
‡ See page 61.
§ See page 84.

February 3d, 1904.—The meeting was called to order at 8.40 P. M., Alfred Craven, Director, in the chair; Charles Warren Hunt, Secretary; and present, also, 75 members and 11 guests.

The minutes of the meeting of January 6th, 1904, were approved as printed in *Proceedings* for January, 1904. The approval of the minutes of the Annual Meeting was deferred until they are printed in the *Proceedings* for February, 1904.

A paper, by R. A. Thompson, Assoc. M. Am. Soc. C. E., entitled "Method Used by the Railroad Commission of Texas, Under the Stock and Bond Law, in Valuing Railroad Properties," was presented by the Secretary, who also presented a communication on the subject from E. L. Corthell, M. Am. Soc. C. E.

The subject was discussed by Messrs. J. G. Tait, F. Lavis and W. H. Coverdale.

The Secretary presented a communication from the St. Louis Engineers' Club, inviting members of the Society to use the rooms of the club during the St. Louis World's Fair.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

William Bullard Allen, Birmingham, Ala.
Thomas Henry Handbury, San Francisco, Cal.
Virgil Henry Hewes, New York City.
Henry Lloyd Lyon, Buffalo, N. Y.
William Horatio Sanders, Los Angeles, Cal.
George Edward Sleeper, Boston, Mass.
George Arthur Zinn, Wheeling, W. Va.

As Associate Members.

Robert Jay Bassett, South Chicago, Ill.
Harold Sherburne Boardman, Orono, Maine.
Harry Gilbert Burrowes, Brooklyn, N. Y.
John Bobbs Cameron, Newcastle, Pa.
Edward Cotman Clark, New York City.
Philip Insley Craig, Flemington, N. J.
De Forest Halsted Dixon, Brooklyn, N. Y.
Alfred Kimball Downes, New York City.
Lindsay Duncan, Boulder, Colo.
Carl Hamilton Fuller, Steelton, Pa.
Richard Alexander Given, Memphis, Tenn.
William Granville Gove, Brooklyn, N. Y.
William Kelly, New London, Conn.

George Gebe MacCracken, New York City.
Ogden Merrill, Brooklyn, N. Y.
Clarence Warren Noble, Kansas City, Mo.
Harry Thomas Paterson, Colorado Springs, Colo.
James Wilson Pierce, Cambridge, Mass.
Edward Nathan Prouty, Berkeley, Cal.
Amos Schaeffer, New York City.
Charles Bruce Scott, Pittsburg, Pa.
Walter Evans Spear, New York City.
Alexander Thomson, Jr., Brooklyn, N. Y.
Thomas MacIntire Vinton, New York City.

As Associate.

John French Golding, New York City.

The Secretary announced the transfer of the following candidates, by the Board of Direction, on February 2d, 1904, from the grade of Associate Member to the grade of Member:

As Members.

Howard Carter Baird, Phœnixville, Pa.
Joseph Hooker Cunningham, Portland, Ore.
Francis Winthrop Scarborough, Richmond, Va.

The Secretary announced the election of the following candidates by the Board of Direction on February 2d, 1904:

As Juniors.

William Gomer Davies, Minidoka, Idaho.
Guillermo Gustavo Fischer, Washington, D. C.
Ralph Holt Howes, New York City.
Julian Pierre William Richmond, New York City.
Edward Lawrence Sayers, New York City.
Herbert Spencer, Brooklyn, N. Y.
William Henry Yates, New York City.

The Secretary announced the following deaths:

Thomas Pearman Shanks, elected Member May 2d, 1888; died January 7th, 1904.

William Ward Reed, elected Fellow December 20th, 1872; died January 10th, 1904.

SELWYN MELLON TAYLOR, elected Member October 7th, 1903; died January 25th, 1904.

ALFRED ROSENZWEIG, elected Junior June 7th, 1882; Member January 4th, 1893; died January 13th, 1904.

Adjourned.

February 17th, 1904.—The meeting was called to order at 8.40 P. M., Past-President Alfred Noble in the chair; Chas. Warren Hunt, Secretary, and present, also, 137 members and 25 guests.

A paper by James H. Brace, Assoc. M. Am. Soc. C. E., entitled "Freezing as an Aid to Excavation in Unstable Material," was presented by the author, and illustrated with lantern slides.

A written communication on the paper from George E. Thomas, M. Am. Soc. C. E., was presented by the Secretary, and the subject was discussed further by Messrs. D. E. Moran, E. L. Abbott, T. Kennard Thomson, Werner Boecklin, H. J. Campbell, Emil Diebitsch, J. G. Tait and H. Reed.

The Secretary announced the following deaths:

George Thompson De Forest, elected Associate Member, December 4th, 1895; died July 25th, 1901.

Benjamin Burgh Smith, elected Member, November 7th, 1888; died February 7th, 1904.

The Secretary made an announcement in relation to the International Engineering Congress to be held at St. Louis during the Annual Convention of the Society.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 12th, 1904.—8.30 P. M.—(Adjourned from January 5th.)—President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Craven, Croes, Knap, Kuichling, Osgood, Pegram, Schneider and Wilgus.

The meeting was devoted to further consideration of the arguments for and against the joining of this Society in the proposed Union Engineering Building, for presentation to the Annual Meeting, and a statement was formulated and adopted.

The following resolutions were adopted for presentation to the Annual Meeting:

"The Board of Direction recommends the adoption by the Annual Meeting of the following resolutions."

"(1) *Resolved*, That the Board of Direction be instructed to issue a letter-ballot, to be canvassed at the Meeting of the Society, March 2d, 1904, on the question whether this Society shall become one of the Constituent Societies in the occupancy and control of the proposed Union Engineering Building, under the terms outlined by the Joint Conference Committee."

"(2) *Resolved*, That should a majority of the votes cast be favorable, the Board is authorized to proceed in the matter, provided the exemption from taxation of the proposed building is assured, and the interests of the Society are otherwise fully safe-guarded."

The President was authorized to appoint a General Committee to take charge of the organization and management of the International Engineering Congress.

Charles Hermany, M. Am. Soc. C. E., was selected from the membership of the Society as a member of The John Fritz Medal Board of Award.

Adjourned.

January 20th, 1904.—The Board met during the Annual Meeting as required by the Constitution, Charles Hermany in the chair; Chas. Warren Hunt, Secretary, and present also Messrs. Buck, Craven, Croes, Curtis, Davison, Deyo, Ellis, Gowen, Jackson, Knap, N. P. Lewis, Mead, Modjeski, Noble, Osgood, Pegram, and Webster.

The following Standing Committees were appointed :

Finance Committee : S. L. F. Deyo, R. S. Buck, William J. Wilgus, L. F. G. Bouscaren, Charles S. Gowen.

Publication Committee : George H. Pegram, Alfred Craven, Joseph O. Osgood, George S. Davison, Hunter McDonald.

Library Committee : Nelson P. Lewis, E. C. Lewis, Ralph Modjeski, William Jackson, Chas. Warren Hunt.

A Committee on Membership was also appointed.

Mr. Hunt then retired.

Chas. Warren Hunt was unanimously elected Secretary for the ensuing year.

Mr. Hunt, having been advised of his election, returned.

Messrs. Croes, Noble, and Craven were appointed a committee to act with the Secretary in the preparation of the letter-ballot and accompanying statements on the proposed co-operation of this Society in the Union Engineering Building.

The Secretary was instructed to issue, as soon as possible, the Report in Full of the Annual Meeting, covering the discussion on the proposed Union Engineering Building.

The Secretary presented the present status of the proposed International Engineering Congress, and a new committee was appointed consisting of all the members who had been appointed by the President of the St. Louis Exposition, together with the present Publication Committee of the Society.

Adjourned.

February 4th, 1904.—8.30 P. M.—Vice-President Deyo in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Buck, Craven, Croes, Ellis, Gowen, Jackson, Knap, N. P. Lewis, Osgood, and Pegram.

Action was taken in regard to members in arrears for dues.

A letter was received from certain members of the Society residing in Brooklyn, making inquiries on certain matters connected with the proposed Union Engineering Building. A reply to this inquiry was determined upon in detail.

The resignations of Roscoe B. Jackson, Jun. Am. Soc. C. E., and E. B. Naylor, Jun. Am. Soc. C. E., were accepted.

Applications were considered and other routine business transacted.

Three Associate Members were transferred to the grade of Member, and seven candidates for Junior were elected.*

Adjourned.

---

* See page 47.

REPORT IN FULL OF THE FIFTY-FIRST ANNUAL MEETING, JANUARY 20th and 21st, 1904.

Wednesday, January 20th, 1904.—The meeting was called to order at 10.15 A. M.; President Alfred Noble in the Chair; Charles Warren Hunt, Secretary, and present also about 300 members. Meeting Called to Order.

THE PRESIDENT.—The minutes of the meeting of January 6th, 1904, in accordance with the custom, will be printed in the January number of *Proceedings*, and come up in due course for action at the meeting of February 3d, 1904. In view of this fact, the reading of the minutes will be dispensed with, unless some call is made for them.

The reading of the minutes will be dispensed with.

The Chair will appoint as Tellers to canvass the ballot for officers, Messrs. A. W. Trotter, H. M. Rood and B. C. Collier. The ballot does not close until twelve o'clock, noon, but in order to enable a report to be made as soon after the hour as possible, the counting will proceed. The ballots will be received up to twelve o'clock, and at that hour the ballot will be declared closed. Tellers appointed.

The report of the Board of Direction will be presented by the Secretary. Report of the Board of Direction.

The Secretary read the report of the Board of Direction.*

On motion, duly seconded, the report of the Board of Direction was received and placed on file.

THE PRESIDENT.—The report of the Secretary.

The Secretary read his report.†

On motion, duly seconded, the report of the Secretary was received and placed on file.

THE PRESIDENT.—The report of the Treasurer, Mr. Knap.

The Treasurer read his report.‡

On motion, duly seconded, the report of the Treasurer was received and placed on file.

THE PRESIDENT.—The appointment of the Nominating Committee. In accordance with the requirement of the Constitution, requests have been sent out to members to make nominations for the members of the Nominating Committee for each district. The Secretary will read for each district the result of those requests. It will then be in order for any member to move the election of any person nominated. Nominating Committee.

THE SECRETARY.—The nominations for the First District are as follows:

District No. 1.—Total number of votes received, 112; distributed as follows:

ALBERT CARR	28
CHAS. L. HARRISON	23
ALEX. RICE MCKIM	18

* See *Proceedings*, Vol. XXX, p. 7 (January, 1904).
† See *Proceedings*, Vol. XXX, p. 14 (January, 1904).
‡ See *Proceedings*, Vol. XXX, p. 16 (January, 1904).

Nominating Committee (Continued).

H. A. La Chicotte	4
J. Waldo Smith	4
S. W. Hoag, Jr	3
L. L. Tribus	2

The following have received one vote each:

J. A. Bensel,
L. L. Buck,
Wm. H. Burr,
Geo. H. Clark,
Francis Collingwood,
Theo. Cooper,
George B. Cornell,
E. L. Corthell,
Wm. B. Fuller,
Charles H. Graham,
Allen Hazen,
Wm. R. Hillyer,
Henry Hodge,
R. C. Hollyday,
T. J. Long,
Geo. W. McNulty,
Daniel E. Moran,
Charles H. Myers,
Edw. P. North,
John F. O'Rourke,
James Owen,
Wm. Barclay Parsons,
Henry B. Seaman,
M. R. Sherrerd,
D. McN. Stauffer,
Geo. W. Tillson,
M. A. Vielé,
Edw. Wegmann,
Samuel Whinery,
F. Stuart Williamson.

On motion, duly seconded, Albert Carr, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the First District.

The Secretary.—The nominations for the Second District are as follows:

District No. 2.—Total number of votes received, 75; distributed as follows:

Frederick Brooks	20
W. H. Moore	17
Edwin D. Graves	8
S. E. Tinkham	4
C. Frank Allen	3
H. A. Miller	3
J. R. Worcester	3
A. S. Cheever	2
X. H. Goodnough	2

The following have received one vote each:

J. P. Cotton,
Arthur W. French,
Frank W. Hodgdon,
C. M. Ingersoll, Jr.,
Wm. Jackson,*
George A. Kimball,
Henry Manley,
Leonard Metcalf,
Mace Moulton,
A. T. Safford,
Edmund K. Turner,
Leonard C. Wason,
Henry B. Wood.

On motion, duly seconded, Frederick Brooks, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Second District.

* Ineligible.

THE SECRETARY.—The following are the nominations for District No. 3:

District No. 3.—Total number of votes received, 25; distributed as follows:

H. A. VAN ALSTYNE	4
WM. A. HAVEN	2
JOHN KENNEDY	2
LOUIS H. KNAPP	2
OLIN H. LANDRETH	2
A. H. SUTERMEISTER	2

The following have received one vote each:

E. A. BOND,
R. S. BUCK,*
C. L. CRANDALL,
G. J. FIEBEGER,
EDWIN A. FISHER,
GEO. S. GREENE, Jr.,*
E. B. GUTHRIE,
E. H. MCHENRY,
CHAS. M. MORSE,
PALMER C. RICKETTS,
E. G. SPILSBURY.

On motion, duly seconded, H. A. Van Alstyne, M. Am. Soc. C. E., was appointed as member of the Nominating Committee for the Third District.

THE SECRETARY.—The nominations for the Fourth District are:

District No. 4.—Total number of votes received, 105; distributed as follows:

H. R. LEONARD	43
L. Y. SCHERMERHORN	35
GEO E. THACKRAY	3
J. A. ATWOOD	2
C. B. HUNT	2
S. T. WAGNER	2

The following have received one vote each:

KENNETH ALLEN,
E. M. BIGELOW,
GEO. S. DAVISON,*
J. S. DEANS,
M. T. ENDICOTT,
L. M. HAUPT,
J. F. HAYFORD,
D. J. HOWELL,
WM. HUNTER,
THOS. H. JOHNSON,
MORRIS KNOWLES,
THEO. A. LEISEN,
D. E. MCCOMB,
MANSFIELD MERRIMAN,
CHAS. M. MILLS,
F. H. NEWELL,
EMIL SWENSSON,
J. C. TRAUTWINE, Jr.*

On motion, duly seconded, H. R. Leonard, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Fourth District.

---

* Ineligible.

Nominating Committee (Continued).

THE SECRETARY.—The following are the nominations for the Fifth District:

District No. 5.—Total number of votes received, 100; distributed as follows:

JOSEPH B. DAVIS	40
JOHN W. ALVORD	18
WM. M. HUGHES	10
GEO. A. MARR	3
CHAS. L. STROBEL	3
GEO. H. BENZENBERG	2
E. E. HASKELL	2
D. W. MEAD	2

The following have received one vote each:

H. F. BALDWIN,
GEO. H. BREMNER,
CLARENCE COLEMAN,
J. T. FANNING,
JULIAN GRIGGS,
E. A. HANDY,
H. E. HORTON,
ROBT. W. HUNT,
H. G. KELLEY,
GEO. W. KITTREDGE,
CHAS. F. LOWETH,
H. W. PARKHURST,
H. E. RIGGS,
J. W. SCHAUB,
E. C. SHANKLAND,
G. W. VAUGHN,
J. F. WALLACE,*
SAMUEL T. WELLMAN,
E. S. WHEELER,
GEO. L. WILSON.

On motion, duly seconded, Joseph B. Davis, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Fifth District.

THE SECRETARY.—The following are the nominations for the Sixth District:

District No. 6.—Total number of votes received, 71; distributed as follows:

G. B. NICHOLSON	22
G. G. EARL	6
S. BENT RUSSELL	6
CHAS. S. CHURCHILL	3
J. A. L. WADDELL	3
ARTHUR HIDER	2
B. F. THOMAS	2

The following have received one vote each:

T. H. ALDRICH,
WARD BALDWIN,
JOHN L. CAMPBELL,
W. W. COE,
WM. P. CRAIGHILL,
B. L. CROSBY,
W. E. CUTSHAW,
J. A. FAIRLEIGH,
HARRY FRAZIER,
JOHN T. GARRETT,
L. F. GOODALE,
B. M. HARROD,
J. F. HINCKLEY,
J. W. HOOVER.
A. L. JOHNSON,
WYNKOOP KIERSTED,
E. W. VAN LUCAS,
R. C. MCCALLA,
R. MONTFORT,
E. T. D. MYERS,
JOHN A. OCKERSON,
C. D. PURDON,
J. W. SACKETT,
H. M. STEELE,
J. L. VAN ORNUM,
J. S. WALKER,
NISBET WINGFIELD.

* Ineligible.

On motion, duly seconded, G. B. Nicholson, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Sixth District.

THE SECRETARY.—The nominations for the Seventh District are:

District No. 7.—Total number of votes received, 32; distributed as follows:

FRANKLIN RIFFLE	4
WM. H. KENNEDY	2
J. B. LIPPINCOTT	2
CHAS. D. MARX*	2
H. A. SUMNER	2

The following have received one vote each:

ARTHUR ADAMS,	F. W. D. HOLBROOK,
E. B. CUSHING,	ALEX. E. KASTL,
ARTHUR P. DAVIS,	SCOTT KING,
GEO. L. DILLMAN,	S. D. MASON,
W. A. DRAKE,	WM. G. MOLER,
J. E. EARLEY,	A. F. ROBINSON,
C. F. W. FELT,	JAMES D. SCHUYLER,*
ROBERTO GAYOL,	J. H. WALLACE,
C. E. GRUNSKY,	W. H. WENTWORTH,
D. C. HENNY,	E. WRIGHT.

On motion, duly seconded, Franklin Riffle, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Seventh District.

THE PRESIDENT.—The report of the Committee on "Uniform Tests of Cement" will be read by the Secretary. Report of Cement Committee.

The Secretary read the report of the Committee on Uniform Tests of Cement, as follows:

MR. PRESIDENT, AND

MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

GENTLEMEN:—Since the presentation of the Progress Report, at the last Annual Meeting of the Society, your Committee on Uniform Tests of Cement has continued its investigations of the several matters referred to in this report.

A number of laboratory meetings were held, at which representatives from many of the prominent eastern laboratories were present and took part in the investigations which were made,

(1) In accordance with the recommendations of the Committee, and

(2) In accordance with the operators' usual practice.

The results showed a greater accordance when the operators followed the Committee's methods than when each followed his own methods, and in many cases the results obtained by an operator using the methods suggested by the Committee were higher and more nearly uniform than those obtained when he used his own.

The results of the year's work, while not conclusive, are highly gratifying.

*Ineligible.

Report of Cement Committee (Continued).

The following changes in the Progress Report of your Committee have been considered advisable:

Par. 31. Strike out the words "500 grams" "of Cement," and insert after the word "determination," the following: "The same quantity of cement as will be subsequently used for each batch in making the briquettes (but not less than 500 grams)."

Par. 34. Strike out the paragraph and insert: "The Committee has recommended, as normal, a paste, the consistency of which is rather wet, because it believes that variations in the amount of compression to which the briquette is subjected in moulding are likely to be less with such a paste."

Par. 46. Insert at the end the clause: "Sand having passed the No. 20 sieve shall be considered standard when not more than one per cent. passes a No. 30 sieve after one minute continuous sifting of a 500-gram sample."

Par. 70. Insert at the end "or preservation in air."

Par. 72. Insert at the end "a similar pat is maintained in air at ordinary temperature and observed at intervals."

Par. 73. Strike out accelerated test "(a)." The Committee's experiments show that this test is of no practical value within any reasonable period of time.

The following investigations are still in progress:

1. The effect of magnesia (MgO) and sulphuric acid (SO_3) on the quality of the cement,
2. The effect of drying on the determination of specific gravity,
3. The value of suggested changes in the shape of the briquette and the form of the clips,
4. The value of the suggested methods for making the accelerated tests,
5. The proper rate of applying the load in tension tests,
6. The value of a more plastic paste for the neat cement tests,
7. The formula for the determination of the proper percentage of water for mortars, and
8. The substitution of a natural sand for the standard quartz.

These investigations have not been completed, because, for the most part, they extend over long periods of time.

In view of the incompleteness of this work, your Committee cannot present a final report at this time, and requests that it be continued.

Submitted on behalf of the Committee.

G. S. Webster,
Chairman.
Richard L. Humphrey,
Secretary.

Committee:
George S. Webster,
Richard L. Humphrey,
George F. Swain,
Alfred Noble,
Louis C. Sabin,
S. B. Newberry,
Clifford Richardson,
W. B. W. Howe,
F. H. Lewis.

The President.—The report of the Committee is before the meeting. What disposition shall be made of it?

It was moved and seconded that the report be received and placed on file, and that the request of the Committee that it be continued, be approved.

The motion was carried.

THE PRESIDENT.—The Secretary will present a report from the Board of Direction as to the award of prizes. Award of Prizes.

The Secretary read the report.*

On motion, duly seconded, the report was received and placed on file.

THE PRESIDENT.—The Secretary will present a special report as to the Engineering Congress and Society Convention. International Engineering Congress.

The Secretary read the following:

Report in Regard to an International Congress of Engineering.

The Society, as announced in the Annual Report of the Board of Direction, has undertaken the organization and management of an International Engineering Congress, to be held at St. Louis, Mo., during the week beginning October 3d, 1904.

The general plan and scope of this Congress are as follows:

A number of engineering subjects have been selected, each, it is believed, of live interest at the present time. On each of these special subjects, an engineer, especially qualified for the work, will be asked to prepare a succinct review of the development of practice during the past ten years, and to give a brief summary of present practice. At least one such expert in America will be asked to write on each of these subjects, and to confine his paper to American practice. Experts in other countries will be asked to contribute similar papers, covering foreign practice.

The plan is to print, as far as possible, these papers in advance of the date for holding the Congress, so that they will be available for those desiring to discuss them.

It is not the intention to read any papers at the Congress, but to throw open each of the subjects for further discussion.

Promises of papers on twenty or more of the subjects selected have already been received from American engineers, and the project has generally been received with so much interest that it is believed a notable contribution to engineering literature will result.

The acceptance of the invitation of this Society, for a visit to this country by members of the Institution of Civil Engineers some time ago, has resulted in an arrangement by which it is expected that a large party of British Engineers will arrive in New York in the latter part of September, so that, after visiting the Society in its house, they may go to St. Louis during the Congress.

In addition to this, engineers in all other foreign countries will be

* See *Proceedings*, Vol. XXX, p. 3 (January, 1904).

International Engineering Congress (Continued).

invited to join the Congress, and, as the Convention of this Society will be coincident with the Congress, everything points to a very large attendance.

It was moved and seconded that the report be received and filed.

E. P. North, M. Am. Soc. C. E.—Would it not do to move at one time that all these reports be received and filed?

The President.—The Chair may venture to assume that is the desire of the meeting.

H. R. Leonard, M. Am. Soc. C. E.—I think it may be well to add to Mr. North's motion, that the report be approved and filed.

The President.—I will put Mr. North's motion. I think it would be better to confine it to this subject, that the report be received, approved and filed.

The motion, being put to vote, was carried.

The President.—The next paper may give rise to some discussion, and the Chair would request that members, in rising, for the benefit of the stenographer, announce their names.

Proposed Special Committee on Concrete and Steel-Concrete.

The Secretary will present a special report from the Board of Direction in the matter of the appointment of a Special Committee on "Concrete and Steel-Concrete."

The Secretary read the report, as follows:

Report of the Board of Direction in the Matter of the Proposed Concrete and Steel-Concrete Committee.

At the Annual Convention, June 11th, 1903, the following resolution was adopted:

"It is the sense of this meeting that a Special Committee be appointed to take up the question of concrete and steel-concrete, and that such committee co-operate with the Association for Testing Materials, and the Railway Engineers' Maintenance of Way Association, which also have a committee on this subject."

At the regular Business Meeting of the Society, September 2d, 1903, all the necessary preliminary steps were taken, and the matter was referred to the Board of Direction, under Article VI, Section 12, of the Constitution.

The Board of Direction now presents the proposition for the appointment of such Committee, recommending a letter-ballot upon it, and presents herewith arguments for and against such appointment.

Arguments in Favor.

1.—Concrete when used either alone or in combination with steel presents so many advantages over other materials that it will soon be used in the greater part of all engineering structures. This is already the case in Europe.

2.—The results of tests, up to the present time, made in the various laboratories in this country, indicate that unless all tests are

made under exactly the same conditions no comparisons are possible, and therefore the results are in doubt.

3.—The use of this material should be guided by a Committee of this Society. Conclusions reached by such a Committee would carry greater weight on this subject than those of any similar Committee from any other engineering society.

4.—Similar Committees have been appointed by the Railway Engineers' Maintenance of Way Association, and the Association for Testing Materials, and the co-operation of these and similar Committees with a Committee of this Society, would add strength to its conclusions.

ARGUMENTS AGAINST.

1.—The subject is a very comprehensive one, and, if properly carried on, represents a great deal of work.

2.—Experience has shown that in several cases Special Committees to report on engineering subjects have been appointed, and have been continued for years without having accomplished anything, or made a final and conclusive report. Unless, therefore, there is a strong demand for the appointment of a Committee to report on Concrete and Steel-Concrete, a demand which would indicate a prospect of actual accomplishments, it should not be appointed.

By order of the Board of Direction.

CHAS. WARREN HUNT,
Secretary.

JANUARY 19TH, 1904.

A MEMBER.—I move that that be acted on by letter-ballot.

THE PRESIDENT.—Is the motion seconded?

J. J. R. CROES, Past-President, Am. Soc. C. E.—I second the motion. Is it in order to send a question out to letter-ballot presented in that form?

THE PRESIDENT.—Will the Secretary read the requirements of the Constitution?

The Secretary read Section 12, Article VI, of the Constitution.

THE PRESIDENT.—The Chair is of the opinion that the motion is in order. Are there any remarks on the motion?

This vote requires a two-thirds vote of the corporate members present. The Chair will therefore request the corporate members present, who are in favor of the issuing of this ballot, to rise.

The Secretary announced 145 voting in the affirmative.

The President declared the motion carried.

Proposed Union Engineering Building.

THE PRESIDENT.—The Secretary will read the special report of the Board of Direction on the action of this Society on the proposed Union Engineering Building.

The Secretary read the special report.*

* This report has been issued to all corporate members.

Proposed Union Engineering Building (Continued).

THE PRESIDENT.—Since the statement of the 16th inst. regarding the project for a Union Engineering Building was issued by the Board of Direction, a further development of great importance has occurred, which it is my duty to lay before this meeting. This action is not merely of my own determination, but is concurred in and insisted on by all the members of the Board of Direction with whom it has been possible to consult. Through the initiative of the Joint Conference Committee, composed of representatives of the five organizations named in Mr. Carnegie's original offer, an interview was had with Mr. Carnegie at his residence on the evening of the 18th inst. This was attended on the part of the organizations by one representative from each, the American Society of Civil Engineers having been represented by me. It was represented to Mr. Carnegie that preliminary plans of the proposed building, based on estimates of space required, submitted for the several organizations, showed that the amount named by him in his original letter of gift—$1 000 000—would not be adequate for the purpose intended, and approximate estimates of cost of a suitable building were submitted, whereupon he added the following words to his original offer:

"JANUARY 18, 1904.

"Your plans for all the Societies show a greater sum needed. I make it one and a half millions.

(Signed) "ANDREW CARNEGIE."

A certified copy of the original offer with the above paragraph appended is herewith submitted for the files of the Society.

Early in the conference Mr. Carnegie showed great interest and anxiety as to the probable action of this Society, expressing the idea that, in readiness to co-operate, Americans excel all other nationalities, and hence their work is more effective; the hope that this Society would decide to co-operate by a great majority, and not by a mere numerical superiority, and the strongest desire to provide a suitable home for the whole engineering profession. The idea of complete co-operation was constantly on his mind, and he frequently recurred to it as essential to the carrying out of his project. To a suggestion that the details should be proceeded with vigorously, he demurred, saying it would be necessary to ascertain first whether the American Society of Civil Engineers would accept, and by repeated reference, made it clear that he anticipated the acceptance of all the organizations, and allowed uncontradicted the inference that only the acceptance of all five organizations would make the offer effective. Among other expressions one was particularly pointed; that if this Society should decline to come into the project, he would have on his hands the five lots purchased for the Engineering Building, but he did not consider this investment a serious matter.

The conference is reported in some detail because it indicates an

important difference in the status of the project from that heretofore supposed by the Board of Direction, on which its statement has been predicated. The Board has had ample reason to believe that Mr. Carnegie would provide for the other organizations even if this Society decided that its best interests required it to stand apart; and it is not doubted that such was Mr. Carnegie's idea at one time. Now, however, it is clear that his offer should be taken exactly as written to all of the organizations and not to a part, these organizations being the four National Engineering Societies and the Engineers' Club.

It is not intended to convey the idea that Mr. Carnegie, either at this conference or previously, distinctly stated that he would withdraw his offer if this Society should not join in the acceptance, but he left the fear that the non-acceptance by any one would result in a withdrawal of the offer.

THE SECRETARY.—Mr. President, I have a letter which was written by a very old member of the Society, with the intention that it should be read at this meeting at this time.

THE PRESIDENT.—The Secretary will read the letter.

The Secretary read the following letter:

FORT BEAR, WYOMING,
JANUARY 10TH, 1904.

MR. CHARLES WARREN HUNT,
Secretary, American Society of Civil Engineers,
220 West 57th St., New York City.

DEAR SIR: As the decision of the Society will probably be made at its approaching Annual Meeting on the 20th of January, as to its acceptance or not of the proposition of that great philanthropist Andrew Carnegie, I desire to briefly express my views.

As the subject is now understood, Mr. Carnegie stands ready to donate one and a half millions of dollars for the erection of a suitable building in New York City for the joint Headquarters of "The American Society of Civil Engineers," "The American Society of Mechanical Engineers," "The American Society of Mining Engineers" and the Engineers' Club (a purely social club), four distinct Corporations.

I am decidedly opposed to the acceptance of this offer by the American Society of Civil Engineers for the following considerations:

From its inception, something over fifty years ago, by a few Civil Engineers resident in and around New York City (the names of James Laurie, Charles W. Copeland, Julius W. Adams, Alfred W. Craven, James P. Kirkwood and Robert W. Gorsuch are now recalled), the Society has increased from a membership of 40 to 50 (up to the outbreak of our war between the States) to a membership of nearly three thousand at the present time. Its membership embraces, practically, all the leading Civil Engineers of this Country. Its professional papers, issued monthly, will compare favorably in point of ability with those of any similar society, and, as a Society, by its commanding influence, it is, by all odds, the leading Society of Engineers of the Western Hemisphere, as the British Institute of Engineers is of the Eastern Hemisphere.

Proposed Union Engineering Building (Continued).

Although its progress has been phenomenal, much more rapid than either the British Institute or of the leading French Society for a similar length of time (as per report of our Secretary), its progress was retarded twelve and a half years by the advent of that bloody conflict between the States, from 1860 to 1865 (which has immortalized the American Soldier). The smoke of that conflict had not more than cleared away ere the Members of our Society resident in and around New York City (the names given at the beginning of this article being conspicuous) took steps to gather together the remnant of the Society, preparatory to its resuscitation on Oct. 2d, 1867. The Society was reorganized, all the old members in either section of the country were notified, and its onward progress was commenced. Since that date its growth in membership and influence had been phenomenal. From a membership of about 50 in 1867, it has increased to nearly 3 000 at the present time, a membership that for high professional character and ability is not exceeded by any similar society of the world. In going by the number of monthly applications for membership, in a few years the number will increase to 5 000 names, if the Society so desires. Its income will increase proportionately. At present it is sufficient for the monthly publication of professional papers that are of immense benefit to non-resident members, especially to younger members, and causes them to take a personal interest and pride in the Society.

A member, who, as the writer, may have visited the dingy and badly lighted quarters of the Society at 73 William Street as late as 1875, and compares them with the modern, elegant and commodious quarters at 220 West 57th St., is apt to conclude that the Society, as yet, needs no more suitable quarters.

For reasons outlined as above, I earnestly oppose the offer of Mr. Carnegie, coupled as it is with a kind of partnership with other societies, however worthy their object or however high the character of their membership. The Mechanical Engineers and the Mining Engineers might well be domiciled in the same building. The American Society of Civil Engineers should, by all means, have a separate building. In ten or fifteen years a very large building may be needed for library room and its other wants. At present, it seems to me, we need no more commodious quarters. By the time larger quarters are needed, a way will be pointed out to obtain them. I am sure the great philanthropist, Andrew Carnegie, will appreciate the reasons for our declining of his offer (should that be the decision), and it may be he would agree to divide up the donation for each Society. Should the amount be sufficient for greatly enlarged quarters, it should be accepted. Mr. Carnegie has set such a pace, for the men of great wealth, by liberal donations to works of charity and education that, should he not respond to the last suggestion, there will be found others who would consider they honored themselves as well as the cause of science by a donation of such amount and with such conditions as would be acceptable to the Society.

I have been a Member of the Society for more than fifty years and am classed among the "Charter Members" by your report, and with Mr. Meyer and the surviving members of that class. It has been my misfortune to be engaged in life so far from Headquarters as to have attended only a few of the Annual Conventions or participated in the benefits of the Society, except thro' its publications. I have always taken a deep interest in its welfare and have been the means of getting a good many new members.

Now, in the decline of life, I feel a deeper interest than ever, and hope my views as given above will be the views of the Society. I am sure that, could the founders of the Society be consulted, they would coincide with my views.

Very truly,

WILLIAM D. PICKETT,
M. Am. Soc. C. E.

Discussion on Proposed Union Engineering Building.

THE SECRETARY.—Mr. Pickett was elected a Member of the Society on July 6th, 1853. (Applause.)

THE PRESIDENT.—In order to bring the recommendation of the Board before the Society at this stage, the Secretary will read the resolutions which they have recommended for adoption.

The resolutions were read by the Secretary as follows:

"(1) *Resolved*, That the Board of Direction be instructed to issue a letter-ballot, to be canvassed at the meeting of the Society, March 2d, 1904, on the question whether this Society shall become one of the Constituent Societies in the occupancy and control of the proposed Union Engineering Building, under the terms outlined by the Joint Conference Committee.

"(2) *Resolved*, That should a majority of the votes cast be favorable, the Board is authorized to proceed in the matter, provided the exemption from taxation of the proposed building is assured, and the interests of the Society are otherwise fully safe-guarded."

It was duly moved and seconded that the resolutions offered by the Board be adopted.

THE PRESIDENT.—The subject is now before the meeting for discussion.

P. C. RICKETTS, M. Am. Soc. C. E.—Mr. President, I move that the Board be requested to send out with this ballot a statement to the effect that the members here present—a majority of the members here present—are not in favor of accepting the proposition.

The motion was duly seconded.

ROBERT CARTWRIGHT, M. Am. Soc. C E.—Mr. President, in view of the importance to the Society of this question that comes up now before us, in view of the marked influence it may have, I would move, sir, that nothing comes from any man on the floor who is not a member of the Society. I want to cut out all outside discussion or representation. We may have presented to us, as by a lawyer, specious arguments and such representations as will befog us. Now, we are here for business; we want to consider this calmly, quietly, and for the best interests of the American Society of Civil Engineers.

As a non-resident member, I may have strong feelings in the matter. I don't want, at this stage of the game, to second the motion. I want to wait a little while until we have had an opportunity to become educated on the subject. No man will go farther than I will in my respect to Andrew Carnegie. At the same time, we are a child

Discussion on Proposed Union Engineering Building (Continued).

born, we are walking, we have grown from nothing almost to what we are, and we still can grow without any outside assistance. (Applause.)

As one of the old veterans in this Society, I can remember when there were somewhere about 275 in its membership, and now we have somewhere about 3 000. I have grown with it, and in the future we still will grow and have our own home, and not have a half interest. We want to be the whole thing. We are the whole thing. Without any wish to speak against the other societies, I am in favor of all the engineering societies of the land. At the same time, we cannot include these other societies, in my estimation, without detriment to the American Society of Civil Engineers. (Applause.) We have a recognition in Europe and all over the world. That is our membership, and we are second to none, and I want to preserve that. I want that the American Society of Civil Engineers shall not be a kindergarten and have subscriptions to keep it up.

Now, mind, don't misunderstand me. I am not saying one word against Mr. Carnegie's donation. What he has done has been done grandly. At the same time, when his donation includes these other societies and a social club, I draw the line. I belong to the Engineers' Club, but it is not to be supposed that this Society, made up as it is of a world-wide membership, shall have to go through the portals of an Engineers' Club to get into the Society. We take in everything. Our Constitution is wide enough and broad enough to take in any man who has the requisite qualifications. It is all well enough to have these sub-societies, but how long would it be, if you got into this thing, before our little quarter interest in the executive board in that corporation would have to give way to a preponderance of the others, and we would be nothing? That is as it appears to me. Now we are all here, let every man give his true opinion of these things, without any bias. Keep it to ourselves. I make that motion, that no man be allowed to address this Society unless he is a member of the American Society of Civil Engineers.

The motion was duly seconded.

The President.—The Chair hardly thinks it necessary to put that question to a vote. The feeling of the membership is unmistakable, and the Chair will undertake to see that the debate is confined to the membership of the Society. No one else is desired to speak.

The question is upon Professor Ricketts' amendment, adding an additional clause to the resolution proposed by the Board.

E. A. Bond, M. Am. Soc. C. E.—Mr. President, I would like an explanation in regard to the exemption from taxation. I do not understand that question. Do you understand what the method is of this Society being exempted from taxation in case they should decide to take the new location?

Mr. Croes.—Mr. President, we want to know now what we are called upon to vote on at the present time. There seem to be two

resolutions offered by the Board of Direction, and two additional resolutions. What are we called on now to vote on first?

THE PRESIDENT.—The question is upon the adoption of the amendment offered by Professor Ricketts. Will Professor Ricketts state his amendment?

J. F. O'ROURKE, M. Am. Soc. C. E.—Mr. President, I rise to a point of order. My point of order is that Mr. Ricketts' motion is out of order. How we can vote to notify the Society at large that a majority has voted against it now, I do not see. (Applause.)

THE PRESIDENT.—The Chair decides that the amendment offered by Professor Ricketts is germane.

MR. O'ROURKE.—I move an amendment to that motion, then, that the Society also sends out, in case the majority is in favor of it, that fact also.

The motion was duly seconded.

J. N. GREENE, M. Am. Soc. C. E.—I move that the vote on Professor Ricketts' amendment be the expression of the Society.

A MEMBER.—It seems to me this motion of Mr. Ricketts is ill-timed. I think it would be a great deal better, and you would have the matters facilitated and made plainer if you would withdraw that for the present, and let the vote be upon the original motion, and then, afterward, is a better time to make that motion.

MR. RICKETTS.—I will withdraw the motion.

MR. O'ROURKE.—I withdraw my amendment.

THE PRESIDENT.—The question is on the adoption of the resolutions recommended by the Board.

MR. O'ROURKE.—Mr. Chairman, sometimes arguments are made orally and sometimes they are made physically. Some of those are very unpleasant. There is an argument now in favor of a new Society house presented by the occupancy of this room by an audience sufficiently large to fill it and to have cries from the rear of "Louder." This is the Annual Meeting of the American Society of Civil Engineers held in 1904, whose commodious quarters are not sufficiently commodious to take them in. This American Society of Civil Engineers, under its Constitution, can not only receive as members the members of all the other bodies that have been addressed by Mr. Carnegie in his letter, but there are three or four more that the Constitution embraces, all of whom are eligible for membership in this Society, if we carried out the original idea of the Society, and I think that we are doing it as far as we can, and that we are going to continue doing it. We would have a place where all of them could come, and where all of them could have room, whether Mr. Carnegie or the gentlemen themselves furnish the necessary funds to provide the house or provide the land.

If this Society met properly, it would meet with all engineers who are civil engineers, whether they are compelled by circumstances to

Discussion on Proposed Union Engineering Building (Continued).

join the smaller subdivision of that body or not. And the question that we have before us to-day is not the question altogether of whether we are going to hold ourselves as good as we are, being representatives of the American Society of Civil Engineers, or whether we are not going to be swallowed up by one of our smaller subdivisions who really belongs to ourselves, and whose honor is our honor, because we happen to be in the same building with them. Every argument that was made against this motion to-day, as presented in the report on the subject, is as strong and decided a piece of pessimism as anybody can find. What is it? It is only a question whether we are going to get broke because somebody else will; because somebody is brighter than we are, we will be put down in Europe, so that when we go there we will say, "No, I am not a Civil Engineer, I don't belong to the Society of Civil Engineers." Now, that is your pessimism!

Now, if this Society is going to follow in the general line of American progress, it will get on the path of optimism. (Applause.)

The first Society house, in William Street, was not the Society house of a lot of pessimists. The Society house proposed in Thirty-ninth Street is not a Society house of pessimists. Mr. Andrew Carnegie, himself, is not a pessimist. We debated this question of amalgamation long ago; it was always favored, always favored and always voted down. And what are we doing now? We are still debating that same thing and favoring it, some of us, some of us to the extent of $1 500 000, and there is already a motion before the house that the notice that it has been voted down shall be sent out. I believe, Mr. Chairman, that if we have a Society house in which American civil engineers, whether they are called mechanical or civil or electrical, or whatever they are called, so long as they are engineers, that the engineering body will be strengthened. I believe we are all engineers and brothers, and I believe that this project to have the brothers live together in one house is good for all, and at any time it is decided that the quarters provided are too small, the value of that house will build one four times as large and one where they can get away from these high buildings. And the social club that is so awful, by the way, you have got to go into that social club with a jimmy, from all that I can learn.

We are going to have a lot of arguments, and we are going to have men here who want to sit down on this because they love this Society so much. I say they love this Society as a baby, and a fool, and it is no good if you cannot love this Society in connection with other engineering societies. And I say the stronger we are as we view ourselves here, the stronger and better we will appear when viewed in connection with the others that we don't think are as good. I believe in our Society. I believe there never was any other society or any other house, and even if we didn't have a house at all, we would

be a great engineering society, but I do feel that we should follow in the path of progress. Engineers, whose organized effort is the secret of success, ought to organize themselves so they would have the force and momentum of numbers when they wanted to accomplish something as engineers, and not be at the beck of any man who will give $75 a month, and in their profession they will get ten times that. But we are afraid somebody will belong that could not belong to our body. They will not. And we will be all the more noble, embracing them all. (Applause.)

E. E. OLCOTT, M. Am. Soc. C. E.—It seems to me, Mr. President, in this argument, this very interesting paper that has been read *pro* and *con*, they lay entirely too much stress and weight on the management of the Society, as though this Society were to lose its autonomy. This Society will be just the same as it always has, and will go ahead and publish the most valuable papers on civil engineering. It is only a question of tenancy that is coming up before us. It does not seem to me as though it hurt the Society or the standing of the Society. It is only whether we shall accept a present of $1 500 000, or our proportionate part of that, and it is only whether we shall be in the front ranks of progress and co-operation. Now, scientific men in the United States stand for co-operation, and it is one of the greatest glories of our country that there is no rivalry and no niggardliness about our giving to the world the results of our investigations. And we must acknowledge, that, advance as this Society has, and increase in membership as it has, the brilliant, the stirring and the phenomenal things that have been done in engineering have not all been done by this Society, and, possibly in the last two years, the other societies have eclipsed us by astonishing the world by scientific discoveries.

I think that this Society, in the interests of the Civil Engineers, would be committing a great error to decline this offer, which I think only strengthens the Society—in no way weakens it or loses its individuality. (Applause.)

MR. CROES.—Mr. President, I rise to a point of order. This whole discussion is not germane to the question at issue before the Society just now, which is: Shall the Board of Direction submit this to a letter-ballot? Get that out of the way, then we can have a resolution that it is the sense of this meeting that the offer should be accepted, or *vice versa*, whichever way you make it. I take the affirmative in that. To get the sense of the meeting, we want to get the affirmative sense, we don't want to get the negative sense, but we want to get first the proposition: Shall this matter be sent out by letter-ballot? And the first resolution offered by the Board of Direction is the one that wants to be acted upon without amendment at all. Shall this be sent out to letter-ballot? That is the question before us now, and after we decide that, the rest comes.

(Cries of "Question.")

Discussion on Proposed Union Engineering Building (Continued).

THE PRESIDENT.—The Chair will have to decide the point of order, and requests the members to limit their remarks to the question before the meeting, that is, the adoption of a resolution to direct the Board of Direction to submit the question to letter-ballot.

A MEMBER.—When those resolutions are sent out, if they are ordered to be sent out, either at that time or earlier, will there be sent out as a part of the information to the members to vote upon, that portion of the remarks made by the President this morning, adding the statements covered by the meeting of the 18th, as I understand it, of January or December, I have forgotten which; and further, would there be an opportunity to add to the discussion, either written or orally, that can be sent out?

THE PRESIDENT.—That matter can be met by a motion instructing the Board of Direction to do that after the vote is taken on this resolution.

F. S. CURTIS, M. Am. Soc. C. E.—I offer an amendment that it require a two-thirds vote and not a majority vote.

MR. CROES.—That is the second resolution of the Board. We are voting on one resolution at a time.

THE PRESIDENT.—The question is on the adoption of the two resolutions recommended by the Board, and the amendment offered by Mr. Curtis. The resolutions, so far, have been considered as coupled together. Mr. Curtis's amendment to the second resolution is that we should substitute for the word "majority" the words "two thirds." The motion will then read, "Resolved, that should two-thirds of the votes cast be favorable, the Board is authorized to proceed," etc.

A MEMBER.—I move that the Society now take a vote upon the first resolution, afterward proceeding to a consideration of the second resolution.

The motion was duly seconded.

THE PRESIDENT.—If there is no objection, the first resolution is now before the meeting.

H. B. SEAMAN, M. Am. Soc. C. E.—The adoption of the first resolution as to sending out the second resolution, would depend on what the second resolution is going to be. I think the amendment of the second resolution is in order.

FOSTER CROWELL, M. Am. Soc. C. E.—It seems to me there is only one resolution there, divided into two paragraphs, but it is all one resolution. The sending out of the letter-ballot is made dependent upon certain conditions expressed in the second paragraph.

THE PRESIDENT.—The first resolution provides for the sending out of a letter-ballot on the question of whether this Society shall become one of the Constituent Societies in the occupation and control of the proposed Union Engineering Building. The second instructs the Board how to proceed in case the first resolution is adopted by the

membership. The Chair is of the opinion that the question is divisible, and so rules. The question before the meeting, then, is on the adoption of the first resolution.

The adoption of the first resolution, being put to vote, was carried.

THE PRESIDENT.—The question before the meeting is now on the amendment of the second resolution, to strike out the words "a majority," and substitute the words "two-thirds," so that the resolution will read:

"Should two-thirds of the votes cast be favorable, the Board is authorized to proceed in the matter, provided the exemption from taxation of the proposed building is assured and the interests of the Society are otherwise fully safeguarded."

THEODORE COOPER, M. Am. Soc. C. E.—Mr. President, why insist on sending out a statement that two-thirds or less than two-thirds vote for this matter? We are a body of intelligent men, and you are going to send the ballots out to our equals throughout the country, also intelligent. Why not, then, tell them what this meeting does? A majority is in favor, or a majority is against, the resolution. Why not say so? What is the purpose of confining the statement to our absent members that two-thirds did this and or two-thirds did that? (Applause.)

THE PRESIDENT.—The Chair is in some doubt whether the gentleman who last spoke understands wholly the question. The question is on the adoption of one of the resolutions proposed by the Board. The question is on the amendment to that resolution.

MR. COOPER.—That is what I am objecting to, sir.

SAMUEL WHINERY, M. Am. Soc. C. E.—I call attention to the fact that this meeting has no right to say that, in order to pass any matter affecting the interests of this Society, it shall require a two-thirds vote. (Applause.)

JOHN BOGART, M. Am. Soc. C. E.—Is there anything in the Constitution of our Society which enables the Annual Meeting to determine how much of a vote by the membership at large shall carry the projected proposition?

THE PRESIDENT.—Nothing whatever in the Constitution. We are advised by counsel that this meeting, or any meeting, or the Board of Direction, or the Society as a whole, can act upon, adopt or decline to enter into this project. I think that covers the right of this meeting to prescribe a two-thirds vote if it chooses, and the Chair would so rule.

G. W. CATT, M. Am. Soc. C. E.—Aside from the right or wrong, in reference to the two-thirds vote, it seems to me that it is entirely improper that the members here present should undertake to say to those of the vast constituency who are not here present, and who are

Discussion on Proposed Union Engineering Building (Continued).

entitled to just as much voice in this matter as we are, that it should require a two-thirds vote to pass this measure, or any other measure. If a measure of this kind is to require a two-thirds vote, I should say that that question by itself should first be submitted to every member, that he might say whether two-thirds were required or not. (Applause.) It is proper enough that this assemblage of members should express its sentiment one way or another on this or any other proposition, but it is surely not proper that we should undertake to tie the hands and the voices of every other member who is not present, which is at least six or seven times the number that are here.

Mr. Cartwright.—Why not make it a seven-eighths vote as well as a two-thirds vote? Now, they might just as well. Of course, that is politics, you know. I can see through it. I think we can trust the Society to the majority. We three little tailors in Pool Street are undertaking to dictate to the large membership of the Society. A majority always governs, and I would suggest that the parties asking this two-thirds vote should say a seven-eighths vote. The majority governs. That is politics, Tammany and everywhere else.

Mr. Whinery.—Mr. President, Gentlemen of the Society: It is an acknowledged rule in all deliberative bodies and in all organizations, that unless otherwise designated in the organic laws of the organization, a majority of the interests prevail. Now, there are some particular measures designated in the Constitution which require a two-thirds vote. Upon all measures of this kind the Constitution is absolutely silent, and following the law that always prevails under such circumstances, this meeting, and not only this part of the membership of the Society, but if every member of the Society were here, the meeting would have no authority whatever to prescribe that a two-thirds vote should be required.

Gardner S. Williams, M. Am. Soc. C. E.—I rise to a point of order. I should say that it seems to me contradictory to parliamentary usage for a majority or less than two-thirds to prescribe a two-thirds vote.

The Secretary.—Mr. President, may I interrupt the meeting one moment to say it is 12 o'clock, and time to declare the ballot for officers closed.

The President.—I declare the ballot for officers of this Society closed.

Mr. Curtis.—Mr. President, this is something of vital importance. This is something which requires us to give up our home, give up our property, and it seems to me, in order to do that, we ought to have two-thirds in favor of it, but if it is entirely out of order, I withdraw the amendment.

The President.—The Chair understands that the amendment is withdrawn, and the question then recurs upon the adoption of the second resolution.

A MEMBER.—Before we consider this, I would like to ask what would be the status, provided the Society voted in its favor, as given in this first resolution, that this Society become one of the Constituent Societies in the occupancy and control of the proposed Engineering Building under the terms outlined by the General Conference Committee—then if it was found that the building was not exempted from taxation, where would the Board of Direction be? It seems to me that the resolutions as worded would leave the Board of Direction under direct orders to do a thing, and yet the second resolution leaves it to their judgment as to whether they should do it or not.

THE PRESIDENT.—It was intended that the second resolution should qualify the first, and that the Board of Direction, in case of unforeseen obstacles of the nature referred to in the second resolution, would be empowered to delay proceedings.

THE SECRETARY.—Mr. President, may I interrupt once more, in the interest of the record, to ask each gentleman when he gets up to speak, if he will announce his name. It is very difficult to keep track of those who speak, and it may be necessary to get a report of this meeting out very quickly, and in order to accomplish that, if every gentleman will announce his name as he gets upon his feet, it will help very much.

O. LOWINSON, Assoc. M. Am. Soc. C. E.—I merely want to ask one question, before this is put to vote, and that is the question of the status of the Engineers' Club with reference to the project. I would like to ask the President whether the question came up, in the meeting with Mr. Carnegie, of the segregation of the Engineers' Club from the Union Building.

THE PRESIDENT.—It did not.

MR. LOWINSON.—So there is nothing to advise the Society as to whether Mr. Carnegie would agree to the segregation of the building.

THE PRESIDENT.—The matter has never been discussed with Mr. Carnegie in any way to my knowledge.

C. R. HARTE, Assoc. M. Am. Soc. C. E.—Mr. President, whatever is determined in this matter will be largely done by those outside of those present to-day, the vast majority being the outside members. It seems to me in this vote we ought to state, not merely that the majority voted not to call for a two-thirds vote, but make the statement as to what proportion of the Society voted for a change to the new building, and what proportion did not. I had in mind to ask, when Professor Rickett's motion came forward, that it be amended that all letters from the older members regarding this building be sent out, also, with the letter-ballot. And it seems to me that as the vast majority of the outsiders really have little to do with the house, except very occasionally, that the action taken by the men here in New York

Discussion on Proposed Union Engineering Building (Continued).

and by the older members, who are particularly conservative, should in a large measure govern their vote, and for that reason I move, when this vote be taken, that the action of this meeting be designated, and that some idea of what proportion of the votes cast were in favor of the proposition, be stated.

(Cries of "Question.")

THE PRESIDENT.—The question is on the passage of the second resolution.

It being duly put to vote, was carried.

EUGENE W. STERN, M. Am. Soc. C. E.—I move the following, that there be issued with the resolution, recommending the ballot, by the Board of Direction, a statement of the conditions required for membership in the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, and also a statement of their present financial condition.

The motion was duly seconded.

MR. CARTWRIGHT.—Why not embody also in that the conditions and requirements of the Engineers' Club? (Applause.)

A MEMBER.—I want to ask whether any recognition has been made by the Society of Mr. Carnegie's offer.

THE PRESIDENT.—Yes.

MR. SEAMAN.—If the last speaker will include the Engineers' Club, I would like to second that motion.

MR. STERN.—I accept that.

MR. O'ROURKE.—Mr. President, is there anything in this matter before us which includes the Engineers' Club? As I understand, Mr. Carnegie did not address the Engineers' Club in his communication, did he?

THE PRESIDENT.—He did.

JOSEPH M. KNAP, M. Am. Soc. C. E.—I hope that last motion will be withdrawn. It seems to me it is making light of this matter, and I do not think we should proceed on this line. I hope the gentleman will withdraw that motion. We don't want to go to work and investigate the financial condition of brother societies. No doubt they are all right, as we are. I hope that will be withdrawn, because it won't amount to anything, and only makes a trivial matter of the whole thing.

MR. COOPER.—Why is that not of any importance? We are going to make them our partners. Don't you inquire into the standing of your partners? We are going to give the property into the hands of nine directors representing them, and we only have three. Are we going to do it without examining the standing of our partners? No. We want to know the standing of the people we are going to put this property into the hands of. When we are going into this and we have only three votes to their nine, where are we as owners? Why shouldn't we examine into it?

MR. WILLIAMS.—Mr. President, it seems to me that the propositions covered by the last motion are abundantly provided for in the resolution already passed, which says that the interests of the Society are otherwise wholly safeguarded, and I see no reason why this Society should publish broadcast to its own members, and thereby to other people, what our views may be or what the apparent condition of our sister societies is. I think the Board of Direction is abundantly able to take care of that phase of the question for us, and I see no reason why this Society should run the risk of arousing the enmity which must necessarily be aroused by the sending out of such documents. It can only be looked upon by the other Societies as a slur upon their methods of doing business, or on their less fortunate condition.

MR. BOND.—Recently we called for examinations, under the Civil Service rules of the State of New York, for positions in the State Engineer's Department, numbering 240. I find by the newspapers that 2 400 applicants have applied to the Civil Service Commission to take those examinations. We are proposing to spend $101 000 000 in the construction of a barge canal through the State of New York. You, gentlemen, are familiar with the amount of money being spent in this great city for public works. I think it stands us in hand to weigh this matter carefully, basing our action on broad foundations as presented by Mr. O'Rourke here to-day. I think that, if these other Societies that have been mentioned are in a poor financial condition, the future will provide for the American Society of Civil Engineers, so that if they are so unfortunate as to have to drop out of this building we can take it and carry it. To-day we have a membership of something like 3 000, as I am told. In the proportion that we get applications under the Civil Service, it is only a short time before our membership will be 30 000. Now, we should look at this thing in a broad light, I think. I think that our friend at the rear of the hall ought to withdraw his motion. I think if our friends are not as prosperous as we are, that they should not be shown up to the world. We have nothing to be afraid of. I think that this matter should receive the careful attention of this meeting to-day, and I think it is well that the action of this meeting should go out to other members who are not present. But to hold up the financial condition of our less fortunate friends, it seems to me, is a great mistake. (Applause.)

MR. STERN.—The resolution is offered in that form merely to bring out all the facts in the case, so that they should be submitted to the judgment of the members of this Society. Statements have been made in the circular issued by the Board of Direction in a manner suggesting that the financial condition of these different Societies was not good, was not sound. I therefore have moved this resolution simply to bring out the facts. The financial statements of all these Societies are public property. It simply means that they be compiled

Discussion on Proposed Union Engineering Building (Continued).

and issued with the letter-ballot. I have to take exception to the remark of one gentleman who stated that this was not a serious motion. I wish to assure the gentleman that the motion has only a serious purpose. If we are here to pass on a very important question, the members of this Society certainly should be presented with all the facts.

MR. KNAP.—I take exception to the statement that the report sent out by the Board insinuates anything against any of the other societies. We say nothing against the other societies, and do not wish to. I think, sir, that the publication or sending out of statements to our 3 000 members as to the financial standing of these other societies will be in reality making it public, and I think we should avoid that, and I do not think it is called for in any way, shape or form, and I hope that motion will be voted down. I simply say we wish to take into account and investigate the whole matter thoroughly eventually, and the Board proposes to do that under this resolution. That will not be neglected at all, but this manner of doing it I do not think is advisable.

MR. GREENE.—Mr. President, it seems to me that this matter would be quite cleared up if we could get an answer to one question here—I mean this financial matter. Is there anything in this proposition, or in this business at all, that compels a merger of the financial conditions of all these four societies when they do come together, if they ever do. If there is not anything of that kind in it, then why is it not true that every tub will stand on its own bottom, and what odds does it make to our Society whether either one of the three are so well off or not so well off or better off than we are? Now, if there is any such information, and the Chair will give it to this house, I think we will clear away this question about going into an investigation of how much money these people are worth, or what their prospects are. Is there anything of that kind in it, Mr. Chairman?

THE PRESIDENT.—Can the Secretary answer that question?

THE SECRETARY.—I don't think that I understand the question exactly. Mr. Greene, will you repeat your question, and I will try and answer it?

MR. GREENE.—My question is this: Is there anything in this arrangement, if this proposition is accepted, that merges and makes all these four societies merge into one as to their financial condition, or does each society stand by itself as we do now, only we occupy one building instead of a half a dozen?

THE SECRETARY.—There is no merger at all, as I understand it, except that each of these associations is to put its money, or its promises to pay, into a general corporation. In one sense there is a merger of the financial interests of the societies, because they will each be constituent holders of the property, but as to merging the

finances of either of the societies or any of them together, there is no such proposition.

MR. COOPER.—If there should be a default of either of the other societies, are we not responsible? We are equal partners. This is a matter of business. I have the highest respect for these other societies, and would not hurt their feelings for the world, but we are looking out for ourselves. That is a pretty important point in this world.

MR. OLCOTT.—Mr. Chairman, I have read over very carefully the proposition as made. My opinion is that it seems plain that all this Society does is to become responsible for paying the interest on one-fourth of the real estate investment—call that five hundred and odd thousand dollars—we become responsible to pay 4% on that amount of money. I do not see that there is any merger at all.

MR. GREENE.—If this thing is a corporation, I think the gentleman's law will not hold good. If it is a corporation, that covers all these societies; then if there is any default, the whole corporation is responsible for that debt.

MR. CARTWRIGHT.—That is an open matter too. All who understand partnerships know that one partner is liable for all the debts of the concern. Now, we are going into this thing. Here is a hat, and we are all asked to chip in what we have got. What are we going to get for it? It is a Mormon marriage. (Laughter.) We are talking here all the time of four societies. This offer was made to five, four Scientific Societies and one social club, share and share alike. Now, if Mr. Carnegie will, in his wisdom and his generosity—nobody thinks more of him than I do—will separate that, it will be a step in advance. But I do not favor putting our money—we have got that; it is ours; we have made it—I don't favor putting that into the general hat to be drawn out by every Philippine that comes in. I have the greatest sympathy for all these sister societies, but I do not propose that we shall pay the expenses of housekeeping for them. We will pay our own, but what are we to do with our accumulation, if there is any? It is a trust and a merger. Is the American Society of Civil Engineers going to have these two hundred and fifty or three hundred thousand dollars, or are they to put it in the hat and every fellow make a grab for it?

THE PRESIDENT.—Mr. Secretary, can you inform the meeting how the information desired can be obtained?

THE SECRETARY.—I think, Mr. President, it would be rather a delicate matter for this Society to issue an official statement of the financial condition of another body. The only way in which we could do that properly would be to get a certificate from the governing bodies of those societies as to what their financial condition is. I doubt very much whether the Board of Direction of this Society would care to

Discussion on Proposed Union Engineering Building (Continued).

take a statement made up by themselves from the published statements of the other societies and publish it officially, unless it was vouched for by the treasurers of the other societies. I know that the Secretary would not care to take that responsibility.

T. L. CONDRON, M. Am. Soc. C. E.—Mr. President, may I ask if these statements are not already published annually by the several societies, much as they are by the American Society of Civil Engineers?

THE SECRETARY.—I think, Mr. President, that if that motion were made, that the last financial statement as published by each of the several societies be published with this, that it would make clear what is intended, from the standpoint of the Secretary.

MR. STERN.—I make that change. I intended that.

THE PRESIDENT.—Will Mr. Stern state the motion as he now desires it?

MR. STERN.—That there be issued with the resolution recommending the ballot, by the Board of Direction, a statement of the conditions required for membership in the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, and also the Engineers' Club, also the last published statement of their financial condition.

MR. GREENE.—I move that that motion be divided, and that the vote be taken on the first part of it, on the qualifications of membership in the societies, and leave the question of financial condition for a second resolution. All these proceedings are to be read by the Society shortly, and the membership at large has already read what has been said and what is already known by our Society about the financial condition of the other societies. It is hardly necessary to send that out in a special circular now for their information. I think all the members of the Society at large must know what the relative condition of the other societies is, and it is hardly necessary. If this motion is divided and a vote taken on the first part of it, as to the qualifications for membership in those societies, I think that will answer the purpose. I move that amendment to the motion.

Seconded.

THE PRESIDENT.—There being no remarks, the question will be put to vote on the motion:

"That there be issued with the resolution recommending the ballot, by the Board of Direction, a statement of the conditions required for membership in the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, and also the Engineers' Club."

A rising vote being taken, the Secretary announced 153 votes for the motion and 80 votes against. The Chair declared the motion carried.

THE PRESIDENT.—The stenographer will read the other part of the motion.

Read by the stenographer as follows.

"Also the last published statement of their financial condition."

MR. WHINERY.—May I ask a question?—Is this an amendment or a part of the motion?

THE PRESIDENT.—It is a part of the motion. The original motion was divided into two parts, of which this is the second part.

MR. WHINERY.—Mr. President, and Gentlemen of the Society, I hope this meeting will consider very seriously and deliberately what we are now proposing to do here. In the first place, there seems to be a generally mistaken idea as to what this whole measure involves. It has been stated distinctly that it does not involve their finances, but it seems necessary to go farther and inquire what it does mean. As I understand the whole purpose—and I do not wish to be understood here as speaking in favor of the measure of combination or against it, at the present time, but merely on this particular point. What is involved, as I understand it, is this: It is proposed that the societies jointly invest in a certain tract of land for the purpose of erecting a building thereon for the joint occupation of the societies. It is not proposed that the investment in that land shall be a partnership affair at all. It is to be held by a separate corporation, separate and distinct from any of the societies, or from all of them. That corporation, it is true, is to be made up of representatives from each of the societies. Now, this corporation will ask each society to purchase and be responsible for a certain amount of the bonds, its share of the bonds issued to pay for this property—just the land—for the tract of land on which the building is to be erected. This Society purchases and holds one-fourth or one-fifth, whichever it may be, of the amount of bonds issued to pay for that property, and will have those bonds as property, and should they become worthless, we lose the amount. That is all there is in that. Now, further than that, each Society is asked to go into this building, which it is proposed to erect, without any cost to the Society, and to pay its share of the operating expenses of this building—nothing more. This corporation that it is proposed to form, to hold this property and administer it, can assess certain rentals, certain expenses of the management of the building against each society. They can do nothing further than that. I see no merger in that whatever. I do not see any partnership in it; I do not see even any entrance of this Society as a society into a corporation in which it is directly a member.

I think it is important that the responsibility that this Society shall actually assume be carefully separated from the burden which it seems to be the impression here the Society is to assume. We do not assume responsibility for this vast enterprise alone. We assume responsibility for only certain things. So much for explanation.

Now, I do not see, under these circumstances, of what benefit it

Discussion on Proposed Union Engineering Building (Continued).

would be to this Society to know the exact financial status of these other societies or what their standards of membership are to be. We are not uniting with them. The membership of this Society, if this measure be adopted, will be just as independent of each of the other societies as it is to-day—absolutely. The other societies attain no rights in the management of this Society by this proposed combination. This Society attains no rights in the management of the other societies. Now, in this matter where are we interested in the financial standing of these societies or their standard of membership? Why, if it were merely a question whether we should occupy that building with a law firm, I see no objection to it whatever. I do not think the fact that this Society, together with a law firm or a medical association or a single doctor, should agree together for their mutual benefit to erect this building and use it jointly—I do not see that it would in any way disparage this Society. It is merely a question of mutual occupation for the common benefit of all, and it seems to me we are going too far, entirely farther than is necessary, for this Society to inquire into the standards of membership or the financial condition of the existing societies. (Applause.)

ELWOOD MEAD, M. Am. Soc. C. E.—Mr. President, I wish to make an inquiry. I do not believe that a great many members knew what they were voting on in regard to sending out an inquiry regarding the standards of admission in the other societies. I certainly know that I did not understand that I was voting on that matter. I understood it was Mr. Greene's amendment we were voting on. If we were considering the original resolution, I wish to reconsider it, because I am certainly opposed, and see no reason for sending out any information as to standards of membership in the other societies. That is simply a piece of impertinence on our part. (Applause.) There might be some propriety for our sending out information as to their financial standing, and I understood I was voting to separate that question, and I move for a reconsideration of that vote.

THE PRESIDENT.—The Chair will be glad to consider a question for reconsideration after the disposition of the present motion, which is on the second half.

MR. CARTWRIGHT.—One moment, please. We are threshing out; we are getting information. Now, as my friend Whinery puts it, it is all very good, but suppose for one minute these other societies are delinquent, they don't pay their interest—who is going to pay the interest? We have got to, or else we are deprived of the benefit of that trust, that Shipbuilding Trust, as I consider it. We want to know where we are at, and what we have got and what we are to do with it. If we make the partnership, it is a plain question. Put it to yourselves as business men; it is a business proposition. We are going into partnership and can't do anything else, in this building. Now, who is

liable for the debts, the whole of us, or every member of the firm? Now, answer that question and then I will see better, and know where I am at.

JAMES H. HARLOW, M. AM. SOC. C. E.—I think, Mr. Chairman, if the membership will read the first half of the third page, that a good many of their questions will be answered. As I read the fourth paragraph, we become possessors of perhaps one-quarter of the bonds of an institution that is bonded for about twenty-five per cent. of its valuation. If this corporation that we are talking of cannot raise the necessary funds by assessment on the various associations, then it may be there will be a default in interest; if a default in interest, then the corporation possibly may foreclose, on a foreclosure sale. If our Society, owning one-fourth of the bonds, perhaps, chose to buy them in and get a two million dollar corporation, there is nothing to prevent it, and it seems to me it is a pretty good business proposition. (Applause.) It seems to me that is the way to look at it. We are owners of one-fourth of the bonds, I mean if we go into it. Now, it seems to me it is not a shipbuilding trust at all, because a shipbuilding trust has "X" number of bonds in excess of valuation; we have got a valuation and one-fourth perhaps in the bonds, which is a pretty safe investment. It seems to me that is the way that part of it should be looked at, and it seems to me that asking for the financial condition of our sister societies is objectionable at least. It seems to me that we should let them alone as we want to be let alone, and as an investment on our part, if they default, perhaps it will be a good thing.

F. S. ODELL, M. AM. SOC. C. E.—I believe there is a motion before the house to reconsider the original vote.

THE PRESIDENT.—No, sir; the pending motion is on the adoption of the second part of the resolution offered by Mr. Stern, which the stenographer will read, so as to make it certain the meeting understands it.

The stenographer then read the second part of Mr. Stern's motion.

MR. ODELL.—I merely wish to say that my understanding of the paragraph referred to was, not that the American Society of Civil Engineers took only one-quarter of the bond issue; the meaning it conveyed to me was that it took more like one-half, and in the event of failure of any of the other institutions, we would have to bear our share.

MR. HARLOW.—If they only have one-half, we will have that much less to buy in in case of foreclosure.

MR. MEAD.—There has been a motion to reconsider the vote on the first paragraph of this resolution; that has been seconded, and I believe claims precedence over a vote on the second paragraph.

THE PRESIDENT.—The pending motion before the meeting was at that time the passage of the second part of this resolution, and the Chair rules that that motion is before the meeting.

Discussion on Proposed Union Engineering Building (Continued).

It was duly moved and seconded that the motion just read by the stenographer be laid on the table, which motion, being put to vote, was carried.

MR. MEAD.—Now, Mr. Chairman, I wish to move a reconsideration of our vote on the first paragraph of that resolution.

THE PRESIDENT.—The Chair understands that the gentleman voted in favor of the passage of the resolution?

MR. MEAD.—Yes, sir.

A MEMBER.—Seconded.

THE PRESIDENT.—The motion is the reconsidering——

MR. NORTH.—I rise to a point of order. I think the man who seconds it voted against it. I think both the mover and the seconder should have voted for it.

MR. MEAD.—The gentleman who seconded it did not vote at all.

THE PRESIDENT.—There is no motion before the meeting.

MR. WILLIAMS.—I rise to a point of order.

THE PRESIDENT.—State the point of order.

MR. WILLIAMS.—The point of order is, having laid on the table an amendment to a motion before the house, we have thereby carried with it the original motion.

THE PRESIDENT.—The motion laid on the table was not an amendment; it was the second part of a resolution which has been divided by the meeting into two parts.

MR. MEAD.—The reason for this reconsideration——

THE PRESIDENT.—The Chair does not understand that there is a motion before the house. In order to bring the motion for reconsideration before the meeting, it would have to be moved and seconded by gentlemen who voted in favor of it.

MR. MEAD.—It has been so seconded.

A MEMBER.—I second the motion.

THE PRESIDENT.—The motion before the meeting is on the reconsideration.

MR. MEAD.—The reason for moving this reconsideration is that the matter was placed before the house in such a fashion as to lead to confusion. Mr. Greene moves an amendment to a motion, the mover of that motion does not second it, and it could only come as an amendment to the original motion by being voted on by the house. I understood that we were voting on Mr. Greene's amendment. I found, after I had voted in favor of that amendment, that I had been voting on the original motion, and I could not have voted, nor could anyone else, according to parliamentary law, have voted on that original motion in the way it came before the house. Now, if I had known what I voted on, I should have voted just the opposite way. I voted believing I was voting for the separation, for the reason that I believe that part of the resolution has no place in the action of this Society. I can

see no reason for this Society to concern itself in the qualification for membership in another society of equal standing with ours. We are not merging with them. There is no reason whatever why we should concern ourselves with their standard of membership or the number of members. We may concern ourselves with the financial standing.

MR. NORTH.—Before that question is put, I should like to say one word, or perhaps two or three, upon this subject, because it seems germane at this time to say it, and not have the thing taken by piecemeal.

Knowing nothing of law, and having much interest in this question, I went to a lawyer whom I thought had some knowledge of corporation law, and submitted to him certain questions in regard to this proposed amalgamation of the four societies. He said: "In buying this land, will you become tenants in common? If you do, why then any part can be sold out. Or, will you be joint tenants? If you are joint tenants, then on the decease or failure of any component part of the amalgamation, you succeed to their holdings and rights in the amalgamation." I told him I did not know and did not understand before that there was any difference between a joint tenant and a common tenant. Oh, yes, says he, there is a great difference. I am sorry I cannot give his learned and technical words, but if the meeting will excuse me, I will refer to the questions that came up partially, and I will read from the circular of the 18th of November, as some people do not have it, the second and third paragraphs.

"2.—The property represented by land, buildings and equipment of the Engineering Societies shall be held and administered by an executive corporate body, preferably under a special charter to be obtained from the State of New York, each of the constituent societies being entitled to name from its membership three persons to act as incorporators and thereafter as directors.

"3.—Each society annually to elect or appoint, as their By-Laws may prescribe, one of their voting members to serve on the Board of Directors of the Executive Corporation, for a term of three years; a vacancy in said Board to be filled by an appointment made by the society the retirement of whose representative causes the vacancy."

And that is one of the arguments in the circular of the 16th in favor of it. Now, if we are joint holders in this affair, on the failure of any constituent member or one of the four, we succeed to his rights; but if we are tenants in common under this act, then the portion of the constituent member failing may be sold out. We, undoubtedly, would be able to buy it, but we would have to bid in the common market for it. Now, we find that there is no provision for loss of representation in case any society becomes delinquent, and if a society becomes delinquent, and we at that time are not able to buy its share, any one—another society or a private individual—might buy its share and take as full and complete control of that building, as I understand it, as we might.

Discussion on Proposed Union Engineering Building (Continued).

MR. CARTWRIGHT.—Is it not stated there that the other societies shall have the first right to purchase any of these bonds that may in any manner come on the market?

MR. NORTH.—Under an execution, I don't think that that would work, although I am not a lawyer and I cannot state. At the end of this conversation, my legal friend said to me, "This is a very important matter, and you should get the very best legal advice that is possible." Said I, "Will that settle it?" "Oh, no!" (Laughter.) Said I, "What will settle it?" He answered, "The Court of last resort." Now, gentlemen, we are asked by some to make what you might call a polygamous marriage, to make it under the rules of the Roman Catholic Church which does not recognize divorce even for the statutory cause. When we make this connection, it is made for life, the life of the four societies, and the only way we can get out of it is to go out of it and leave what we have, unless some law can be devised which will save us. I do not know whether or not that law can be devised, and my legal friend did not know whether or not it could, but he said we should get the very best legal advice possible, and that wouldn't settle it. I don't think it is very well to buy a pig in a poke of that kind. It might be.

There is one point here I wish to refer to—it is a little outside of this question that is now before the house, but I do not want to get up again, and I ask the kindness of the meeting to hear me for one word or two more—that is, that we should enter upon the project with a firm determination to avoid dissension and make it helpful and healthful. That is on page 8 of the circular of January 16th. Now, in the beginning of last June, at the meeting of last June, most of the people attending it were to a large extent our guests. It is perhaps impolite to use such a term as a "snap judgment," and I will not use it, but that meeting came to our Society House with a set of resolutions and a telegram for Mr. Carnegie thoroughly prepared, which they proposed rushing through, which said it was an official meeting of the four societies, as I understood at the time, and I objected to it. This left a very unpleasant impression on my mind, the desire to commit the American Society in a meeting that was not called by the Society, and, I think, was not called through the Society—at least I knew of it only incidentally, and received no written notice of it. And the case has been further complicated lately by a circumstance to which I may refer more directly: the refusal of two at least of those societies, and possibly the third, to join us in an engineering congress at St. Louis. I believe—I say this subject to advisement—but I believe that the refusal to join us in an engineering congress was such a reply as did not admit of any further negotiation. Now, we do not, as I look upon it, wish to make an arrangement for life with three other societies, two of whom, at least, are at this time more or less

hostile to us, and some of whom tried to use the Society's name to accomplish their ends without due warrant for such use.

I think an engineer, and I believe everybody here present will agree with me perfectly and thoroughly, who undertakes to do a piece of work before he has carefully looked, not only at the possibilities of doing it, but at the difficulties that he will meet, is taking money unworthily and dishonestly. And before we sink, or at least venture, our entire capital and our reputation in an enterprise of this kind, I think that all the difficulties, Mr. President, should be fairly looked at and thoroughly met in the minds of the President and the Directorate of this Society.

Now, one of the important things in this arrangement, as it looks to me, is the financial and the professional standing of these three other societies we are asked to join. We have a great interest in the financial affairs, because we are not strong enough of ourselves to carry the $540 000 that that land will cost—

MR. WILLIAMS.—Mr. President, I rise to a point of order. The question before the house is the reconsideration, as I understand it—

MR. NORTH.—I will accept that point of order before it is acted on. I merely asked the indulgence of the meeting to extend my remarks.

W. C. LAMBERT, Assoc. M. Am. Soc. C. E.—I desire to say just a word in favor of the reconsideration. When the original question was under debate, it was very clearly stated that the Engineers' Club was to be one of the affiliating societies. It seems now, on a careful reading of the matter at the bottom of page 1 and the top of page 2, although it is to be made to apply to five corporations, the final arrangement does not include the Engineers' Club, and that the joint or common tenancy that we are asked to enter into is only with those other three organizations. The question is on our common or joint tenancy with the three societies holding the property on Thirty-ninth Street. I did not understand that that question was put. I am in favor of its reconsideration.

The motion for the reconsideration being put to vote, was carried.

THE PRESIDENT.—The question is now upon the original motion, which the stenographer will read.

"That there be issued with the resolution recommending the ballot, by the Board of Direction, a statement of the conditions required for membership in the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, and also the Engineers' Club."

A rising vote being taken, the Secretary announced 45 votes in favor of the resolution and 116 votes in opposition.

The Chair declared the resolution lost.

MR. WILLIAMS.—I move we adjourn, if there is no other business.

Ballot for Officers.

THE PRESIDENT.—I hope the motion to adjourn will be withdrawn. There is but very little business more to be brought before the meeting. The Secretary will read the report of the Tellers.

The Secretary read the report, as follows:

Report of Tellers Appointed to Canvass the Ballot for the Election of Officers at the Annual Meeting, January 20th, 1904.

MR. PRESIDENT:—The tellers appointed to canvass the ballots for officers respectfully report as follows:

Total number of ballots received		697
Not entitled to vote	2	
Without signature	12	
	—	14
Counted and found correct		683

For President:

Charles Hermany	674
C. C. Schneider	2
G. B. Kittredge	1
J. A. L. Waddell	1
C. A. Haswell	1
R. Hering	1
W. B. Parsons	1
A. Ziesing	1
Blank	1

For Vice-Presidents:

F. S. Curtis	677
S. L. F. Deyo	676
W. B. Parsons	1
X. H. Goodnough	1
Jas. Dun	1
H. A. Carson	1
W. H. Burr	1
L. L. Buck	1
H. G. Kelley	1
H. A. Miller	1
Wm. Hood	1

For Treasurer:

Joseph M. Knap	683

For Directors:

Charles S. Gowen	679
N. P. Lewis	676
John W. Ellis	676
George S. Webster	678
Ralph Modjeski	668
Charles D. Marx	674
H. A. La Chicotte	1
R. C. Hollyday	2
Chas. Warren Hunt	1
V. C. Bogue	1

Geo. B. Francis	1
Chas. H. Haswell	1
R. A. Cairns	1
E. P. Dawley	1
G. F. Swain	1
F. P. Stearns	1
Edgar Marburg	1
J. B. Davis	2
G. E. Ellis	1
Jas. Dun	1
L. E. Cooley	1
F. W. Cappelen	1
Onward Bates	1
W. W. Curtis	1
J. D. Isaacs	1
F. A. Molitor	1
B. S. Wathen	1
R. B. Burns	1

ALFRED W. TROTTER,
H. M. ROOD,
B. C. COLLIER,
Tellers.

JANUARY 20TH, 1904.

THE PRESIDENT.—I declare the following gentlemen elected:

As President, Charles Hermany;

As Vice-Presidents, F. S. Curtis and S. L. F. Deyo;

As Treasurer, Joseph M. Knap;

As Directors, Charles S. Gowen, N. P. Lewis, John W. Ellis, George S. Webster, Ralph Modjeski and Charles D. Marx.

The Secretary will make some announcements.

The Secretary then announced certain features of the programme.

President Hermany Introduced.

THE PRESIDENT.—In laying down the high office with which you entrusted me a year ago, I desire to say that my sense of the honor conferred has been a constantly increasing one, and my sense of the obligation that I am under to the Society has also been increasing. I will now request Mr. Croes and Mr. Cartwright to conduct the President-elect to the chair.

Gentlemen, it is my high privilege to present to you your President, Mr. Charles Hermany. (Applause).

CHARLES HERMANY, President, Am. Soc. C. E.—Gentlemen, Members of the American Society of Civil Engineers, Professional Brethren, as I have known you to be for lo, these many years, I thank you for the honor you have conferred upon me upon this day. In the history and the affairs of the Society, the Annual Meeting is an occurrence of interest and importance. To me it has been on this occasion an event somewhat startling. Notwithstanding the fact that it is so, I can thank you for the honor conferred. In undertaking the assumption of an office of this kind, as I have stated, it is somewhat startling. The

duties devolving upon the executive are varied and important, and, while I enter upon them with some hesitation, notwithstanding that, when I remember the long intimate relations with the men into whose faces I am now looking, I feel assured that with their co-operation, guidance and assistance, there cannot any task come before this Society that we cannot manage successfully and creditably. I thank you again for the honor conferred. (Applause.)

THE SECRETARY.—Gentlemen, I am requested by the President of the Society to say that the meeting of the Board of Direction, which is required by the Constitution at the Annual Meeting, will be held in the Secretary's office at half-past two, and the members of the Board of Direction are respectfully requested to get there as near that time as possible.

The Society then adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE FIFTY-FIRST ANNUAL MEETING.

Wednesday, January 20th, 1904.—After the business meeting, lunch for about 450 members was served at 1.30 P. M. at the Society House. At 3 P. M. a large party, under the guidance of S. L. F. Deyo, M. Am. Soc. C. E., Chief Engineer, and George E. Thomas, M. Am. Soc. C. E., Supervising Engineer of Power-House, Interborough Rapid Transit Company, visited the new power-house of that company at Fifty-ninth Street and Eleventh Avenue. The stations and various parts of the Rapid Transit Railroad were also inspected during the afternoon.

At 9 P. M. there was a Reception, with dancing, in the Society House, at which the attendance was about 300.

Thursday, January 21st, 1904.—The day was devoted to an excursion to Boonton and Little Falls, N. J., by invitation of the Engineers and Contractors of the works. The party left New York at 9.30 A. M. on a special train over the Delaware, Lackawanna and Western Railroad, furnished by the courtesy of William H. Truesdale, President, and proceeded to Boonton, where, under the guidance of J. Waldo Smith, M. Am. Soc. C. E., Consulting Engineer; and Edlow W. Harrison, M. Am. Soc. C. E., Chief Engineer, of the Jersey City Water Supply Company, the Boonton Dam and the Conduit for the water supply of Jersey City were inspected. The party afterward visited the filtration works and pumping station of the East Jersey Water Company, at Little Falls, N. J., where lunch was served. After inspecting the works the members and their guests returned to New York, arriving at 5.15 P. M.

In the evening there was an informal "Smoker" at the Society House, about 450 members and guests being in attendance.

The following list contains the names of 493 members, of various grades, who registered as being in attendance at the Annual Meeting. The list is incomplete, on account of the failure of many members to register, and it does not contain the names of any of the guests, of the Society or of individual members:

Abbot, F. W. ...... New York City
Abbott, E. L. ...... New York City
Adams, Arthur ...... Utica, N. Y.
Aiken, W. A. ...... Pittsburg, Pa.
Allen, W. A. .... Maurer, N. J.
Allen, W. F. .... New York City
Allen, W. H. ...... Brooklyn, N. Y.
Auryansen, F. .... Brooklyn, N. Y.
Babb, C. C. ... Washington, D. C.
Bacon, John W. . Danbury, Conn.
Bailey, Geo. I. ... New York City
Baird, H. C. .... Phoenixville, Pa.
Ball, C. B. .... New York City
Bamford, W. B. .. New York City
Bance, C. W. ... Jersey City, N. J.
Barbour, F. A. .... Boston, Mass.

Barnes, W. T......Boston, Mass.
Barney, P. C....Brooklyn, N. Y.
Barnsley, G. T.....Oakmont, Pa.
Basinger, J. G....New York City
Beerbower, G. M..New York City
Belknap, W. E....New York City
Benton, Lewis S..New York City
Berger, Bernt.....New York City
Betts, R. T..... Brooklyn, N. Y.
Beugler, E. J......Boston, Mass.
Bissell, H.........Boston, Mass.
Blakeslee, C...New Haven, Conn.
Boecklin, W......New York City
Bogart, John.....New York City
Boller, Alfred P..New York City
Bond, Edward A...Albany, N. Y.
Bouton, G. H..Jersey City, N. J.
Bowers, George....Lowell, Mass.
Bowman, A. L....New York City
Boyd, J. C... ....New York City
Brace, J. H.......New York City
Brackenridge, J. C.,
Brooklyn, N. Y.
Braine, L. F.......Newark, N. J.
Bramwell, G. W. New York City
Braslow, Barnett..New York City
Briggs, Josiah A..New York City
Brodhead, Calvin E.,
Wilkes Barre, Pa.
Brooks, Fred......Boston, Mass.
Brown, Le Grand,
Rochester, N. Y.
Brown, T. E......New York City
Brunner, John......Chicago, Ill.
Bryson, Andrew....Reading, Pa.
Buchholz, Chas. W.,
New York City
Buck, R. S.....Montreal, Canada
Bullock, W. D..Providence, R. I.
Burdett, F. A.....New York City
Burpee, Moses.....Houlton, Me.
Burr, W. H.......New York City
Burrowes, H. G..Brooklyn, N. Y.
Bush, Edw. W...Hartford, Conn.
Bush, H. D.......Baltimore, Md.

Carlile, T. J....Philadelphia, Pa.
Carpenter, G. A.,
Pawtucket, R. I.
Carr, Albert......New York City
Cartwright, R...Rochester. N. Y.
Catt, Geo. W.....New York City
Cattell, W. A.....New York City
Chambers, H. J...New York City
Chambers, Ralph H.,
New York City
Chase, R. D......New York City
Chibas, Edwardo J.,
Santiago de Cuba
Christian, G. L...New York City
Christy, G. L.....New York City
Clark, G. Hallett..New York City
Clarke, G. C......New York City
Clarke, St. John....Bogota, N. J.
Clausnitzer, John,
Brooklyn, N. Y.
Codwise, E. B....Kingston, N. Y.
Coffin, T. Amory..New York City
Cogswell, W. B..Syracuse, N. Y.
Cole, H. J........New York City
Collier, B. C......New York City
Collingwood, F..Elizabeth, N. J.
Condron, T. L..... Chicago, Ill.
Conrow, H........New York City
Cook, John H....Paterson, N. J.
Cooke, Chas. H...New York City
Coombs, S. E.....New York City
Corthell, A. B.....New York City
Corthell, E. L....New York City
Coverdale, W. H..New York City
Crandall, C. L......Ithaca, N. Y.
Crane, C. A.......New York City
Crane, F. E...Amsterdam, N. Y.
Crane, W. E... .Brooklyn, N. Y.
Craven, Alfred....Yonkers, N. Y.
Croes, J. J. R.....New York City
Crowell, Foster...New York City
Cuddeback, A. W., Paterson, N. J.

Dakin, A. H., Jr...New York City
Darwin, H. G....New York City

Davies, J. V......New York City
Davis, Chas.......Allegheny, Pa.
Davison, Geo. S...Pittsburg, Pa.
Deans, Jno. S...Phœnixville, Pa.
Devin, George....Hoboken, N. J.
Deyo, S. L. F.....New York City
Diebitsch, E .....New York City
Dorrance, W. T...New York City
Dougan, J........New York City
Dougherty, R. E..New York City
Douglass, A. C.,
Niagara Falls, N. Y.
Drew, C. D......Brooklyn, N. Y.
Duncklee, John B.New York City
Dunham, H. F....New York City

Easby, M. W...Philadelphia, Pa.
Edwards, J. H.....Oxford, N. Y.
Edwards, W. R...Baltimore, Md.
Ehle, Boyd.....East Creek, N. Y.
Ellis, J. W.....Providence, R. I.
Endemann, H. K..New York City
Erlandsen, O......New York City
Evans, J. M......Brooklyn, N. Y.
Evans, M. E......New York City

Fairchild, J. F.Mt. Vernon, N. Y.
Falk, Myron S....New York City
Farley, Philip P..Brooklyn, N. Y.
Farrington, H.....New York City
Ferguson, G. R...New York City
Fetherston, J. T.,
New Brighton, N. Y.
Fiebeger, G. J..West Point, N. Y.
Field, W. P........Newark, N. J.
Fish, J. Charles L.Palo Alto, Cal.
Fisher, Francis D..New York City
Fletcher, Robert..Hanover, N. H.
Flinn, Alfred D...New York City
Ford, F. L.......Hartford, Conn.
Ford, W. H.....Philadelphia, Pa.
Fort, E. J.......Brooklyn, N. Y.
Foster, E. H......New York City
Fox, W. G...Bulls Bridge, Conn.
Francis, Geo. B...New York City
Francis, H. N....Arlington, R. I.
Fraser, Chas. E...New York City
French, A. H....Brookline, Mass.
French, A. W...Worcester, Mass.
French, J. B.....Brooklyn, N. Y.
Frost, Geo. H.....New York City
Frost, Geo. S.....New York City
Fuller, Frank L....Boston, Mass.
Fuller, G. W......New York City
Fuller, Wm. B....Paterson, N. J.
Furber, W. C...Philadelphia, Pa.
Furman, J. R.....New York City

Gahagan, W. H..Brooklyn, N. Y.
Gardiner, F. W....New York City
Gardner, M. L.....Newark, N. J.
Garrison, F. L...Crandull, Tenn.
Gartensteig, C.... New York City
Gay, Martin......New York City
Gerber, E.........Pittsburg, Pa.
Gifford, Geo. E....New York City
Gillespie, R. H....New York City
Goldsborough, J. B.,
Croton-on-Hudson, N. Y.
Goodell, John M..New York City
Goodnough, X. H..Boston, Mass.
Goodrich, E. P...Brooklyn, N. Y.
Gould, E. S.......Yonkers, N. Y.
Gould, W. T.....Brooklyn, N. Y.
Gowen, C. S......Ossining, N. Y.
Graham, C. H ....New York City
Granbery. J. H..Elizabeth, N. J.
Grant, T. H.....Red Bank, N. J.
Grantham. H. T.Philadelphia, Pa.
Gray, J. C........New York City
Gray, J. H........New York City
Gray, W..........New York City
Green, B. R...Washington, D. C.
Green, C. N.......New York City
Greene, Carleton..New York City
Greene, F. S......New York City
Greene, G. S., Jr..New York City
Greene, J. N.......Boston, Mass.
Gregory, C. E.....New York City
Greiner, J. E.....Baltimore, Md.

Griffith, L........Yonkers, N. Y.
Grimm, C. R....Brooklyn, N. Y.
Griswold, H. T. Old Lyme, Conn.
Gubelman, F. J...New York City
Gudmundsson, G .Pittsburg, Pa.

Hague, Chas. A...New York City
Haight, S. S......New York City
Hall, L. W......Tuscaloosa, Ala.
Hall, Martin W...New York City
Ham, W. H.......New York City
Hamlin, W. E.....New York City
Hammer, R. H....New York City
Hankinson, A. W..New York City
Hansel, Charles..Rochester, N. Y.
Harlow, J. H.....Baltimore, Md.
Harrington, F. F..New York City
Harrington, J. L.,
West New Brighton, N. Y.
Harris, Elmo G.......Rolla, Mo.
Harrison, C. L....New York City
Harrison, E. W..Jersey City, N. J.
Harte, C. R..Jamaica Plain, Mass.
Harwi, S. J.......Bayonne, N. J.
Harwood, G. A....New York City
Haskins, W. J....New York City
Hauck, W.........New York City
Haviland, A.......New York City
Hayes, E...........Cohoes, N. Y
Hayes, S. W........Geneva, N. Y.
Hazard, E.,
Johannesburg, South Africa
Hazard, S....White Plains, N. Y.
Hazen, Allen......New York City
Hazlett, R......Wheeling, W. Va.
Henderson, J. T..Hartford, Conn.
Henry, Philip W...New York City
Herbert, H. M. Bound Brook, N. J.
Hering, Rudolph..New York City
Hermany, Chas....Louisville, Ky
Hickok, H. A......Newark, N. J.
Hildenbrand, W...New York City
Hillyer, Wm. R...New York City
Hoffman, N. B. K..New York City
Holliday, A. R....New Castle, Pa.

Hollyday, R. C...Brooklyn, N. Y.
Hone, F. de P......New York City
Hopkins, G. G., Jr..Brooklyn, N. Y.
Howe, E. W.... ..Boston. Mass.
Howe, H. J........New York City
Hoyt, William E..Rochester, N. Y.
Humphrey, R. L. Philadelphia, Pa.
Hunt, Chas. W....New York City
Hunt, R. W.........Chicago, Ill.
Hunter, R. E...Montreal, Canada
Hutchinson, Cary T. New York City

Ilsley, A. B........Boston, Mass.
Irwin, J. C........New York City
Ives, A. S......Philadelphia, Pa.

Jackson, William..Boston, Mass.
Jacoby, H. S........Ithaca, N. Y
Jarrett, Edwin S..New York City
Johnson, L. E......Steelton, Pa.
Johnson, L. J..Cambridge, Mass.
Johnson, W. S.....Boston, Mass.
Jordan, W. F......New York City
Just, Geo. A......New York City

Kaufman, G.....Brooklyn, N. Y.
Keays, R. H.......New York City
Keith, H. C.......New York City
Keller, O. B.......New York City
Kelley, W. D......New York City
Kenney, E. F...Philadelphia, Pa.
Khuen, Richard...Ambridge, Pa.
Kimball, George A..Boston, Mass.
King, C. C.,
West New Brighton, N. Y.
King, Wallace., Jr. New York City
Kinsley, T. P......New York City
Knap, E. D.......New York City
Knap, J. M........New York City
Knickerbacker, John..Troy, N. Y.
Knowles, M.......Pittsburg, Pa.
Kolb, Henry J....New York City

Labelle, H. F..Philadelphia, Pa.
La Chicotte, H. A. New York City

Landreth, O. H. Schenectady, N. Y.
Landreth, W. B.... Albany, N. Y.
Lavis, F.......... New York City
Leavitt, C. W., Jr.. New York City
Lee, E. H........... Chicago, Ill.
Leonard, H. R.. Philadelphia, Pa.
Lesley, R. W... Philadelphia, Pa.
Lewis, F. H...... Craigsville, Va.
Lewis, N. P....... New York City
Livingston, J. I. Bound Brook, N. J.
Long, E. M....... New York City
Loomis, Horace. Mt. Vernon, N. Y.
Lowinson, Oscar... New York City
Ludwig, Alfred.... New York City
Lundie, John...... New York City

MacCracken, G. G.. New York City
Macdonald, A. A.. New York City
MacGregor, R. A.. New York City
Machen, H. B..... New York City
MacNaughton, James,
Tahawus, N. Y.
McCann, T. H.... Hoboken, N. J.
McComb, C. O.. Watertown, N. Y.
McComb, D. E.. Washington, D. C.
McDonald, H. P., Jr.,
Jersey City, N. J.
McHarg, Leslie... New York City
McKenzie, T...... Westerly, R. I.
McKenzie, T. H.. Hartford, Conn.
McLean, A....... Brooklyn, N. Y.
McMinn, T. J..... New York City
Magor, H. B...... New York City
Maignen, J. P. A. Philadelphia, Pa.
Marden, H. H., Jr.. New York City
Marple, W. M...... Scranton, Pa.
Mason, Francis.... New York City
Mason, Geo. C.... New York City
Matcham, Chas. A.. Allentown, Pa.
Matheson, J. D... Mexico, Mexico
Mayer, Joseph.... New York City
Mead, E ..... Washington, D. C.
Melick, N. A...... New York City
Merriman, M.,
South Bethlehem, Pa.

Metcalf, L......... Boston, Mass.
Meyers, C. W..... New York City
Miller, H. A....... Boston, Mass.
Miller, H. C...... New York City
Miller, R. P...... New York City
Mills, C. M..... Philadelphia, Pa.
Miner, C. A.... Wilmington, Del.
Modjeski, Ralph.... Chicago, Ill.
Moisseiff, Leon S. New York City
Moncure, W. A. Philadelphia, Pa.
Monsarrat, N. D. Columbus, Ohio
Montony, L. G... ...Troy, N. Y.
Moore, W. H.. New Haven, Conn.
Mordecai, A..... Cleveland, Ohio
Morse, C. M....... Buffalo, N. Y.
Moss, R. E....... New York City
Myers, C. H ... New York City
Myers, John H... New York City

Nichols, C. H.. New Haven, Conn.
Noble, Alfred..... New York City
Noble, F. C...... Brooklyn, N. Y.
Norris, R. V. A.. Wilkes Barre, Pa.
Nutter, C. H...... New York City
Nye, A. S., Jr..... New York City

Oakley, G. I...... New York City
O'Brien, J. H..... New York City
Odell, F. S... Port Chester, N. Y.
Olcott, E. E...... New York City
Opdyke, S. B., Jr.. New York City
O'Rourke, John F. New York City
Orr, Alex..... Gloversville, N. Y.
Osgood, J. O.... Plainfield, N. J.
Otagawa, M .... Tokyo, Japan
Oxholm, T. S.,
West New Brighton, N. Y.

Paine, Geo. H..... New York City
Parker, A. M..... New York City
Parker, A. W.... Brooklyn, N. Y.
Parker, C. J...... New York City
Parsons, H. de B.. New York City
Parsons, W. B.... New York City
Pegram, Geo. H.. New York City

Pemoff, J. J ......New York City
Perkins, P. S...Providence, R. I.
Peterson, P. A. Montreal, Canada
Pistor, G. E. J.....Newark, N. J.
Pitts, T. D..... ..New York City
Plympton, G. W..Brooklyn, N. Y.
Polk, W. A........New York City
Pollock, C. D....Brooklyn, N. Y.
Post, H. W.......New York City
Potter, Alexander. New York City
Potter, H. W......New York City
Pratt, M. D........Steelton, Pa.
Pratt, W. A..New Brighton, N. Y.
Pratt, W. A....Philadelphia, Pa.
Pressey, H. A..Washington, D. C.
Prichard, Henry S..Pencoyd, Pa.
Prout, H. G......New York City
Purdy, Corydon T. New York City

Quinton, J. H..Los Angeles, Cal.

Ramsey, E. P....Brooklyn, N. Y.
Reynders, J. V. W., Harrisburg, Pa.
Reynolds, J. O....New York City
Rhodes, F. D .....New York City
Rice, G. S........New York City
Richards, J. T..Philadelphia, Pa.
Richardson, C....New York City
Richardson, T. F..Clinton, Mass.
Ricketts, P. C........Troy, N. Y
Ridgway, R.......New York City
Roberts, N.....Jersey City, N. J.
Robinson, A. W., Montreal, Canada
Rosencrans, E. J..New York City
Rosenthal, A..Mt. Vernon, N. Y.
Rowell, George F. Baltimore, Md.
Ryan, M. H.......New York City
Ryder, E. M. T., New Haven, Conn.

Sabin, A. H., Long Island City, N. Y.
Sanderson, J. G....Scranton, Pa.
Saunders, W. L...New York City
Scarborough, F. W., Richmond, Va.
Schaub, J. W ......Chicago, Ill.
Schmidt, M. E....New York City
Schneider, C. C...New York City
Schumann, C. J...New York City
Shepardson, J. E., Shabbona Grove, Ill.
Sherrerd, M. R....Newark, N. J.
Shirreffs, R...Washington, D. C.
Shoemaker, M. N..Newark, N. J.
Sickman, A. F... Holyoke, Mass.
Simpson, Geo.... New York City
Simpson, Geo. F..New York City
Skinner, F. W....New York City
Smith, C. W......New York City
Smith, J. Waldo..Paterson, N. J.
Smith, L. C. L....New York City
Smith, M. H......Yonkers, N. Y.
Snow, C. H.......New York City
Snow, F. H.. .....Boston, Mass.
Snow, J. P........Boston, Mass.
Snyder, G. D.....New York City
Sonne, Otto.......Boston, Mass.
Sooysmith, Chas..New York City
Soper, George A..New York City
Spencer, W. T. New Haven, Conn.
Sperry, H. M.....New York City
Stanton, R. B.....New York City
Stauffer, D. McN..New York City
Steffens, W. F.....New York City
Stehle, F. C.......New York City
Stepath, Chas.....New York City
Stern, E. W......New York City
Stiger, J. S..Bernardsville, N. J.
Stoddard, G. C....New York City
Strawn, T. C......New York City
Swain, G. F........Boston, Mass.
Swensson, Emil....Pittsburg, Pa.
Swinburne, G. W. New York City
Swindells, J. S..Mt. Kisco, N. Y.

Taber, Geo. A.... .New York City
Taylor, C. F.......Boston, Mass.

Taylor, Lucian A..Boston, Mass,
Temple, W. H. G.,
Providence, R. I.
Thacher, Edwin...New York City
Thackray, G. E...Johnstown, Pa.
Theban, J. G......New York City
Thomas, G. E.....New York City
Thomas, S. R., Hokendauqua, Pa.
Thomes, E. H.....Jamaica, N, Y.
Thompson, E. D. Philadelphia, Pa.
Thompson, H. C..New York City
Thompson, S. E.,
Newton Highlands, N. J.
Thomson, A., Jr..Brooklyn, N. Y.
Thomson, G. H...New York City
Thomson, T. K ..New York City
Tidd, A. W.......New York City
Tighe, J. L......Holyoke, Mass.
Tilden, C. J........Ithaca, N. Y.
Tillson, Geo. W..Brooklyn, N. Y.
Tingley, R. H....New York City
Tomkins, Calvin..New York City
Tomlinson, A. T..New York City
Tompkins, E. De V.,
New York City
Trautwine, J. C., Jr.,
Philadelphia, Pa.
Treadwell, L..Portsmouth, N. H.
Tribus, Louis L...New York City
Trotter, Alfred W.New York City
Tucker, Ross F...New York City
Tucker, Wm. C...New York City
Turner, D. L.....New York City
Turner, E. K......Boston, Mass.
Tuttle, Arthur S..New York City

Ulrich, D.........New York City
Upham, R. D.....New York City

Van Buskirk, C. R.New York City
Van Horne, J. G..New York City
Van Winkle, E. B.New York City
Vier, H..........New York City
Vorce, C. B.......New York City
Vredenburgh, W., Jr.,
New York City

Wadsworth. J. E..New York City
Wagner, J. C...Philadelphia, Pa.
Wagner, S. T...Philadelphia, Pa.
Waldron, S. P..East Berlin, Conn.
Ward, C. R......Brooklyn, N. Y.
Waterhouse, J....New York City
Watkins, F. W.,
White Plains, N. Y.
Watson, Merrill...New York City
Webb, W. L....Philadelphia, Pa.
Webster, G. S..Philadelphia, Pa.
Wells, C. E.......Clinton, Mass.
Weston, R. S......Boston, Mass.
Wheeler, R. N....New York City
Whinery, S.......New York City
Whipple, G. C...Brooklyn, N. Y.
Whiskeman, J. P..New York City
Whistler, J. T..Washington, D. C.
White, L.........New York City
White, T. S.....Beaver Falls, Pa.
Whitney, F. O ....Boston, Mass.
Whitson, A. U.,
Croton-on-Hudson, N. Y.
Whittemore, W. F.,
Hoboken, N. J.
Wiggin, T. H....Brooklyn, N. Y.
Wilcock, F......Brooklyn, N. Y.
Wilcox, C. L......New York City
Wild, H. J........Portland, Me.
Wilkins, G. S.....New York City
Williams, B. L., Jr.,
West Orange, N. J.
Williams, C. G...Brooklyn, N. Y.
Williams, G. S.....Ithaca, N. Y.
Williamson, F. S..New York City
Wilson, C. W. S..New York City
Wilson, E. B......Rahway, N. J.
Wölfel, Paul L.Philadelphia, Pa.
Worcester, J. R....Boston, Mass.
Wright, A. W......Pomona, Cal.
Wortendyke, N. D.,
Jersey City, N. J.
Wright, J. Bodine.New York City

Young, C. G......New York City

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, March 2d, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership and ballots on the proposed Union Engineering Building will be canvassed, and a paper, entitled "Substructure of Marsh River Bridge," by Herbert J. Wild, Jun. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, March 16th, 1904.—8.30 P. M.—At this meeting, a paper, entitled "The Location of the Knoxville, La Follette and Jellico Railroad, of the Louisville and Nashville System," by W. D. Taylor, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

A Committee of the Board of Direction is now arranging a programme, with a view to making this Convention an International Meeting of Engineers, for the presentation and discussion of timely subjects of professional interest.

As the details of the arrangements are developed, they will be announced in *Proceedings.*

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an engineering exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

Robert Moore, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
Edward C. Carter, M. Am. Soc. C. E., Chicago, Ill.
Mordecai T. Endicott, M. Am. Soc. C. E., Washington, D. C.
James L. Frazier, " " Frankfort, Ind.
William Jackson, " " Boston, Mass.
Emil Kuichling, " " New York, N. Y.
J. L. Van Ornum, " " St. Louis, Mo.
John F. Wallace, " " Chicago, Ill.
H. J. Pfeifer, Assoc. M. Am. Soc. C. E., St. Louis, Mo., *Secretary.*

International Engineering Congress

UNDER THE AUSPICES OF

The American Society of Civil Engineers

In conjunction with the St. Louis Universal Exposition,

October 3d to 8th, 1904.

COMMITTEE IN CHARGE:

HENRY S. HAINES, *Chairman*, 374 Fifth Ave., New York City.
L. F. G. BOUSCAREN, *Vice-Chairman*, Cincinnati, Ohio.
WILLIAM METCALF, Pittsburg, Pa.
BENJAMIN M. HARROD, New Orleans, La.
ELMER L. CORTHELL, New York City.
ROBERT W. HUNT, Chicago, Ill.
GEORGE W. MELVILLE, Philadelphia, Pa.
GEORGE B. POST, New York City.
PALMER C. RICKETTS, Troy, N. Y.
GEORGE S. DAVISON, Pittsburg, Pa.
CHARLES WARREN HUNT, *Secretary*, 220 West 57th St., New York City
JOSEPH M. KNAP, *Treasurer*, 220 West 57th St., New York City.
WILLIAM P. CRAIGHILL, Charlestown, W. Va.
M. T. ENDICOTT, Washington, D. C.
JOSEPH RAMSEY, JR., St. Louis, Mo.
L. B. STILLWELL, New York City.
M. L. HOLMAN, St. Louis, Mo.
JOSEPH O. OSGOOD, New York City.
GEORGE H. PEGRAM, New York City.
ALFRED CRAVEN, New York City.
HUNTER MCDONALD, Nashville, Tenn.

Preliminary Announcement

February 1st, 1904.

UNIVERSAL EXPOSITION, ST. LOUIS,

1904.

INTERNATIONAL ENGINEERING CONGRESS.

PRELIMINARY ANNOUNCEMENT.

An International Engineering Congress, under the auspices of the American Society of Civil Engineers, will be held at the Universal Exposition, Saint Louis, Missouri, U. S. A., during the week of October 3d to 8th, 1904.

The Congress will be one of a series of International Scientific Congresses to be held at the Exposition under the general authority and with the co-operation of the Director of Congresses.

The development of Engineering Science during the past decade has been so rapid and has extended over so wide a field that the Universal Exposition at Saint Louis seems to be a fitting time at which to review the work of the past and obtain an authoritative epitome of present practice.

The object of the Congress is to secure a thorough International consideration of certain branches of Engineering work which have been selected with special reference to their present interest and importance.

In order to facilitate the work of the Congress and to insure the presentation of topics in a systematic manner, the Committee has prepared the subjoined list of the subjects which have been selected for review and discussion.

It is to be understood that the list of subjects proposed is somewhat tentative, and may be slightly modified as the details of the programme are perfected.

As a basis for discussion at the sessions of the Congress, the Committee has invited engineers specially qualified in each of the various branches covered by the foregoing list, to prepare a review of the development during the past ten years in that branch in the United States, together with a summary

of present practice. Engineers in other countries, experienced in these various lines, will be specially invited to prepare similar papers presenting a review and summary of practice in their respective countries.

It is proposed to print these papers in advance, in order that a full discussion at the various sessions may be elicited without giving up any time to the reading of papers at the Congress.

All engineers in the United States and in all other countries are invited to become members of the Congress, to attend the sessions, and to take part in the discussions; or, if unable to attend, to forward written communications on any of the selected subjects. It is not expected that delegates will be formally appointed, it being intended that an opportunity to attend shall be afforded to any who may wish to become members of the Congress.

The papers, together with the discussions upon them, will be collated and published in one or more volumes by the American Society of Civil Engineers.

The membership fee in the Congress will be $5.00, which will entitle the member to participate in the Congress and to receive a copy of the published proceedings.

All members of the American Society of Civil Engineers will be members of the International Engineering Congress without payment of the membership fee, and will be entitled to receive all the publications of the Congress.

Membership may be secured by forwarding this fee, with name and address, to the Secretary of the Committee, Charles Warren Hunt, 220 West 57th St., New York City, who will issue a receipt therefor. Each member will receive all notices, programmes, etc., issued in advance of the Congress.

LIST OF SUBJECTS:

1. Harbors.
2. Natural Waterways.
3. Artificial Waterways.
4. Lighthouses and Other Aids to Navigation.
5. Traffic on Improved Waterways, as Compared with Seaboard Traffic, and the Effect of this Development on Railroad Traffic.
6. Purification of Water:
   a. For Domestic Use;
   b. For the Production of Steam.
7. Turbines and Water Wheels.
8. Irrigation.
9. Railroad Terminals:
   a. At Ports;
   b. Inland.
10. Underground Railways.
11. Locomotives and Other Rolling Stock.
12. Live Loads for Railroad Bridges.
13. The Substitution of Electricity for Steam as a Motive Power.
14. Sewage Disposal.
15. Disposal of Municipal Refuse.
16. Ventilation of Tunnels.
17. Highway Construction.
18. Concrete and Concrete-Steel Construction.
19. Deep Foundations.
20. The Manufacture of Steel.
21. Tests of Materials of Construction.
22. Passenger Elevators.
23. Pumping Machinery.
24. Dredges: Their Construction and Performance.
25. Steam Turbines.
26. Electrical Power:
   a. Generating Stations;
   b. Transmission.
27. Naval Architecture.
28. Marine Engineering.
29. Dry Docks.
30. Ordnance.
31. Fortifications.
32. Mining Engineering.
   (Sub-Divisions under this heading not yet determined.)
33. Engineering Education.
   (Sub-Divisions under this heading not yet determined.)

REPORT OF THE BOARD OF DIRECTION TO THE FIFTY-FIRST ANNUAL MEETING, JANUARY 20th, 1904, IN THE MATTER OF THE PROPOSED ENGINEERING BUILDING.

The attention of the members of the American Society of Civil Engineers is called to a decision of the question whether:

The Society shall continue as heretofore to occupy its own building;

Or, shall occupy, in common with three other National Engineering Societies, suitable space in a large building owned and controlled by a Corporation composed of an equal number of representatives from each of these Societies.

The manner in which this question has come to be considered by the American Society of Civil Engineers is this:

On February 14th, 1903, Mr. Andrew Carnegie wrote this letter:

"Gentlemen of the
American Society of Civil Engineers,
American Society of Mechanical Engineers,
American Institute of Mining Engineers,
American Institute of Electrical Engineers, and the
Engineers' Club.

"It will give me great pleasure to give say one million dollars to erect a suitable Union Building for you all, as the same may be needed.

"With best wishes,
"Truly yours,
(Signed) "ANDREW CARNEGIE."

Mr. Carnegie has since given verbal assurance that he desires to erect a building adequate in all respects to the needs of the Societies with due provision for future growth, the cost not to be limited to the sum named in his original offer.

At the time the foregoing letter was written, the Engineers' Realty Company, an association formed for the purpose of providing a home for the Engineers' Club, had purchased a plot of land having fifty feet frontage on Fortieth Street and a depth of ninety-eight feet nine inches, half way between Fifth and Sixth Avenues.

A plot of land directly in the rear of this property and fronting on Thirty-ninth Street, with a frontage of one hundred and twenty-five feet, and a depth of ninety-eight feet nine inches, has been purchased by Mr. Carnegie at a cost of $517 000. He proposes to sell this at cost and interest to the four Engineering Societies named in his letter, or such of them as will join in the purchase, after he shall have erected upon it a building (costing approximately one million dollars) to be made adequate to the needs of all the Societies for a long time to come, which building will go with the land without extra charge to the purchasers of the land.

An adequate building will be erected by Mr. Carnegie on the adjoining lots which front on Fortieth Street, and will be similarly conveyed to the Engineers' Club. It should be stated that the representatives of the several Societies, including in this case those of the Engineers' Club, unanimously favor the complete physical separation of the two buildings. Mr. Carnegie has never formally acceded to this, but there is little room to question his acquiescence.

A conference committee of the four Engineering Societies has, after six months' deliberation, formulated conditions for the tenure of the property, the essential points of which are as follows:*

The title of the property shall be vested in an EXECUTIVE CORPORATION, which is to be created by special Act of the Legislature, and is to be composed of twelve persons, three of whom are to be chosen by each of the aforesaid CONSTITUENT SOCIETIES.

The purchase money is to be obtained by the sale of bonds of the EXECUTIVE CORPORATION, bearing interest at four per cent. per annum, and redeemable on six months' notice. Each of the CONSTITUENT SOCIETIES shall have the right to purchase at par, and hold inalienably, a proportion of these bonds corresponding to its interest in the EXECUTIVE CORPORATION. It may hold a larger proportion subject to one year's call of the EXECUTIVE CORPORATION, at par.

To meet the expenses, of interest, taxes (if any), and operation and maintenance, the EXECUTIVE CORPORATION shall assess upon each of the CONSTITUENT SOCIETIES annually, a sum sufficient to meet all obligations, proportioned to the space in the building occupied by such Society, as assigned to it by the Board of Directors of the EXECUTIVE CORPORATION.

Other scientific associations may be assigned space in the building by the EXECUTIVE CORPORATION, and the income derived from the occupants of the building shall be used by the EXECUTIVE CORPORATION for defraying ordinary expenses, establishing a repair and re-building fund and the advancing of engineering arts and science.

The Board of Direction believes that this matter should now be presented to the membership for ballot, although the project is not as yet in shape for such presentation under the instructions of the Asheville Convention. It has been demonstrated, however, that a building with suitable accommodations for all the CONSTITUENT SOCIETIES can be planned on the land selected and already secured.

The Board believes that, in the interest of all the parties concerned, a decision should be reached at as early a date as possible, and it is within the power of the Annual Meeting to order a letter-ballot, on the question as to whether the American Society of Civil Engineers shall becomeone of the CONSTITUENT SOCIETIES in the occupancy and control of the proposed UNION ENGINEERING BUILDING.

To cover this contingency, the Board has prepared the following arguments for and against the project as at present formulated, for presentation to the Annual Meeting.

*For text in full, see Progress Report of the Board on the Project, dated November 18th, 1903.

ARGUMENTS:

IN FAVOR.

1. The Society now has an opportunity to become one of four equal participants in a gift of about one million dollars to be expended for a modern building adequate for the needs of all four Societies for many years to come.

Such a liberal and generous gift has never been offered to the profession before, and such an opportunity to secure a suitable building for a great Engineering Center can hardly be expected to recur.

By the sale of our present property, which need not be hastened, a sufficient amount can be realized to cover the interest of the Society in the land upon which the new building is to be placed, and leave a remainder for broadening the work of the Society.

2. It is desirable to secure co-operation between the different Engineering Societies and the different classes of Engineers. Engineers in different lines of work are not brought together as much as men in other professions, and the facility for meeting friends and widening acquaintance by being housed in a common building would be of especial value to them.

Better opportunities for individual intercourse and facilities for more frequent exchange of ideas and experience must be of benefit to the profession.

The present stage of civilization has been marked by a great development in the applications of science, and its advance has been largely the unrecognized work of the Engineering Profession. Future progress will

AGAINST.

1. *A professional Society should not accept a gift under conditions which may in the future hamper its independence and usefulness.

It is believed that a greater sense of responsibility is produced, and a greater pride engendered, if the members of any organization feel that its support depends entirely upon themselves.

On the assumption that the Engineering Building will cost $1 000 000, the increase of nominal assets of this Society will be about $250 000. As against this, the Society will be deprived of exclusive control of the property it occupies, both as regards its management and the possibility of a change of investment.

The ownership will be inalienable and indivisible, and, with the control of the property, will be in the hands of the EXECUTIVE CORPORATION, in which the Society will have but one vote in four. It is to be carefully considered whether the gain is sufficient to compensate for the sacrifice of independence and individuality.

2. In the practical operation of large buildings, the several floors of which are occupied by different families or business firms or associations of individuals, experience does not always show a gain in social or business affiliations or intimacy between the several tenants, simply because of their proximity.

There is no precedent for anticipating a beneficial result, in this respect, from the occupation of different floors of a large building by different Societies of Engineers, each desirous of preserving its individuality and increasing its membership.

The prestige of the Profession of Civil Engineering cannot be enhanced by the collection in one building of a number of separate organizations with different requirements for membership.

ARGUMENTS:

IN FAVOR.

perhaps be even more marked, and the profession of Engineering should take its place as one of the most important agents in the advancement of civilization and the development of the country. It is urged that this project will aid in accomplishing this end.

Joint occupancy and contiguity of the several organizations in a commodious Engineering Building, centrally located, would tend to the unity and strength of the Engineering Profession as a whole. The present tendency is toward specialization, and hence a segregation, which is to be deplored, and which a closer association would do much to counteract.

3. Our present building, while adequate for ordinary meetings of the Society, is inadequate in some respects for the requirements of the Annual Meeting—the principal occasion when non-resident members visit the Society House. There is no proper accommodation for giving a luncheon on this occasion, unless the Business Meeting is held elsewhere; and, with the rapid increase in membership, these conditions will grow worse from year to year.

The new building will give much more space and better accommodations both in the business offices and the auditoriums; and ample space for a very largely increased membership in all the organizations. A large auditorium, with seating capacity for one thousand persons, and two or three smaller ones, with seating capacity for 200 to 400 each, will provide for all meetings. Suitable provision can be made for the convenient service of luncheon on any occasion.

AGAINST.

It cannot be regarded as unquestionable that a greater intimacy between the several Societies would be mutually beneficial by developing a deeper professional spirit.

The experience of the Institution of Civil Engineers of Great Britain indicates that a certain amount of exclusiveness and conservatism engenders in the members pride in the organization and solicitude for its welfare, and begets in the public a reliance upon its character, which might be jeopardized by such an association with other organizations having different histories, aims and traditions.

If, as may well be feared, joint occupancy of a common building should give rise to dissensions, the result would be a loss of prestige instead of a gain.

3. The present house of the Society is a four-story and basement building of fine architectural appearance, planned and built expressly for it, on a 100-foot street, adjacent to two churches, and opposite to an imposing Fine Arts Gallery. It is fully adequate to all the present needs of the Society excepting only on the occasion of the Annual Meeting. The business offices, library and reading room, will be ample for a considerably increased membership.

When more space is required two or three more stories can be added, or adjacent property can be acquired, when this becomes necessary. The present property is nearly paid for, and the regular annual surplus of receipts over expenditures is steadily increasing; there can be no doubt that the Society can make these enlargements or acquisitions whenever needed.

ARGUMENTS:

IN FAVOR.

The advantages to be gained by the common use of auditoriums, reading rooms, etc., could probably be obtained at less cost of maintenance and operation, than where different establishments are maintained; and the expenses may be partially defrayed by renting office space and auditoriums to other scientific organizations without interference with the work of the CONSTITUENT SOCIETIES.

This feature may be of considerable importance until by increase of membership the space becomes necessary for the use of the CONSTITUENT SOCIETIES, and when this occurs the Societies will be so strong that the burden will be insignificant.

AGAINST.

The experience had in the management of high buildings in New York and elsewhere, is to the effect that the cost of operation, per square foot of floor space occupied, is very much greater in a ten-story building with elevators than in a four- or six- story building without elevator service.

It is the opinion of experts in the management of buildings that the expense to this Society, by becoming a participant in the management of the proposed building, would be very greatly in excess of its present expenditure for operation of its own building.

It is doubted that a building for a home for the several societies, ten stories or thereabout in height, giving adequate architectural effect for suitably impressing the general public, and creating a pride of ownership in the minds of the members of the several societies, can be built on the proposed site, on a narrow street, in the middle of a nine hundred-foot block, likely to be occupied by business buildings of greater height.

At some future date, even with the proposed liberal allowance, the space in the proposed building will become inadequate for one or more of the CONSTITUENT SOCIETIES; all will certainly grow, but the probability is that some will grow at the expense of the others. In this case the proposed Engineering Center will be broken up, as there will be no room for further expansion, and there is sure to be diversity of opinion as to which shall go and which shall stay. This emphasizes the objection to joining in a project which makes no provision for growth, or readjustment, beyond a certain limit.

ARGUMENTS:

IN FAVOR.

4. The collection of the libraries of the various Societies in one building would facilitate greatly making researches, and would result in economy of time and efficiency. Each Society would retain control of its own books, stored in separate stacks.

Each Society could maintain and increase its library with no less freedom than if it occupied a separate building.

A common reading room would serve for all.

5. The new building, centrally placed between the two great railway terminals, and near the hotel district, will be more convenient to non-resident members, particularly to those leaving on late trains.

The proposed building will be about 2 000 ft. from the nearest Subway Station; 2 100 ft. from the Grand Central Station; 3 100 ft. from the new Pennsylvania Railroad Tunnel Station (now under way), that is to say, within 10 or 12 minutes' walk from either of these stations. The 6th Avenue Elevated Station is 1 270 ft., and the nearest East Side Elevated Station is 2 320 ft. distant. The Sixth Avenue surface car line is 500 ft. away, the Seventh Ave. car line is 1 400 ft. away; by which cars the ride to the Pennsylvania Railroad Station would be two minutes; the Forty-second St. Crosstown line is 1 270 ft. away, and the Broadway surface car line 1 000 ft. away.

AGAINST.

4. With the libraries of the CONSTITUENT SOCIETIES under the same roof, there will not be the same incentive for maintaining the completeness of each, as the feeling will be that the other libraries, readily accessible, can be relied upon to contain all books, relating to their specialties, and it might seem a waste of money and space to have in each of the four libraries a copy of the same book; yet it seems desirable to keep the library of this Society, which is a general technical collection, larger and more complete than any other similar library in America, as complete at all times as if the Society occupied independent quarters.

In case of withdrawal at some future time, the library should be as complete as if there had never been any association. It is probable that donations of publications would be restricted to one copy for the building, the several libraries being considered as one, and thus the growth of our Library would be restricted.

5. The new building will be on a 60-ft. street in a district changing from a residential to a business character.

The present building is located on a 100-ft. street in a growing locality. It is 1 000 ft. from the nearest Subway Station, which is 5 minutes' ride from the Grand Central Station, or by walking 250 ft. to the Boulevard surface cars with 8 minutes' ride to the Grand Central Station, or by walking 300 ft. to the Seventh Avenue surface cars with 8 minutes' ride to the Pennsylvania Railroad Tunnel Station. There are five surface lines within a quarter of a mile; Broadway 200 ft.; Eighth Avenue 550 ft.; Seventh Avenue 300 ft.; Sixth Avenue 1 200 ft., and 59th Street Crosstown 800 ft. Two elevated railroad stations are each 1 600 ft. distant.

This location is suitable for the purpose, is attractive and accessible from all directions.

ARGUMENTS:

IN FAVOR. / AGAINST.

Against:

The area of the lot on which the present house is built is nearly one-half of that proposed for all four of the Societies in 39th St.

The price paid for the former in 1896 was $14.48 per square foot; the price we are asked to pay for the latter is $41.89 per square foot, plus the interest to date of occupancy.

In favor:

6. Associations of Engineers should be mutually helpful. If this Society does not join in this project, the burden upon the others will be greater. We are all members of one great profession. We should join hands with our brethren who are engaged in other lines, with the sincere desire that all work together to enhance the strength and influence of the engineering profession as a great unity.

Against:

6. This Society stands for certain principles which individualize its character, among which is the fact that the term "Civil Engineers" used in its title comprehends Military, Naval, Mining, Mechanical and Electrical Engineers, Architects and Marine Architects, as specified in its Constitution, all being eligible for membership.

To be housed in the same building with other societies in which different organizations would be shortly termed "Civil," "Mechanical," "Electrical," "Mining," etc., would lead to a restriction of the proper meaning of the name of this Society in the popular estimation, thus detracting from its dignity and destroying its individuality.

In favor:

7. The building would be under the exclusive control of the representatives of the four National Engineering Societies; these representatives forming an EXECUTIVE CORPORATION in which each Society would have an equal voice.

Such a Corporation, made up of the best men in the CONSTITUENT SOCIETIES, could be depended upon to deal justly with all.

We should enter upon the project with a firm determination to avoid dissensions and to make it successful and helpful.

Possible difficulties should not deter us from joining in an enterprise which, with proper management, may be made a great benefit to the profession.

Against:

7. The management of the new building will be in the hands of an EXECUTIVE CORPORATION representing all the Societies, by which Corporation space and expense will be apportioned.

Once having committed ourselves to this project, however, we would be unable to withdraw without sacrifice of property, and would be obliged to continue the affiliation with the other Societies, even though experiences, now unforeseen, should make it desirable to sever the connection.

The plan of occupation and control of the new building involves an entire and undesirable change in the business management of this Society.

ARGUMENTS:

IN FAVOR.

The danger that any one of the four great National Engineering Societies may become unable to pay its expenses in the new building, seems extremely remote, if we believe in the continued future development of our country, in which all branches of the profession of Engineering will have an important part; but, if the extremely improbable should occur, and any one of the Societies should fail and withdraw, it can hardly be doubted that the others could successfully maintain the building.

Nor can it be reasonably doubted that other engineering or closely allied scientific societies, would avail themselves of any opportunity to locate in the Engineering headquarters, whenever such opportunity might be offered.

AGAINST.

Instead of being independent and retaining entire control of its property, as has so far been done with successful results, the Society will be obliged to surrender control of its real estate to an organization in which it will have only one-fourth interest, the remaining three-fourths being held by other parties.

The proposed EXECUTIVE CORPORATION is to enter upon a speculative business enterprise, viz., the management of a large building, confessedly larger than is demanded by the present needs of the participants in the ownership, in a locality the character of which is now in a transition state from residential to business occupancy, with no great likelihood of future advance in values. Especially can no increase of value be anticipated for a building designed for semi-public uses, the cost of maintaining which will be very great, and will be constant whether it is fully occupied or not.

Participation in such an enterprise is foreign to the aims and objects of the American Society of Civil Engineers, and should not be entered into.

Any loss will fall largely upon the non-resident members of the Society, who constitute three-fourths of its membership, and to whom the possession of an inseparable, fractional share of a large building will be of no benefit.

If any of the CONSTITUENT SOCIETIES default in the payment of interest, the others would face the necessity of assuming an increased burden or of losing their entire investment.

This Society cannot afford to enter into an association in which it might be responsible for the financial failure of others, without adequate protection, which has not yet been assured. This seems a possible danger on account of the present difference in the financial standing of the four national organizations.

The Board ot Direction recommends to the Annual Meeting the adoption of the following resolutions:

(1) *Resolved*, That the Board of Direction be instructed to issue a letter-ballot, to be canvassed at the Meeting of the Society, March 2d, 1904, on the question whether this Society shall become one of the CONSTITUENT SOCIETIES in the occupancy and control of the proposed UNION ENGINEERING BUILDING, under the terms outlined by the Joint Conference Committee.

(2) *Resolved*, That should a majority of the votes cast be favorable, the Board is authorized to proceed in the matter, provided the exemption from taxation of the proposed building is assured, and the interests of the Society are otherwise fully safe-guarded.

By order of the Board of Direction.

CHAS. WARREN HUNT,

Secretary.

NEW YORK,
JANUARY 16TH, 1904.

For action taken at the Annual Meeting, see p. 72.

ACCESSIONS TO THE LIBRARY.

From January 13th to February 9th, 1904.

DONATIONS.*

CHANGE GEAR DEVICES.

Showing the Development of the Screw-Cutting Lathe and the Methods of Obtaining Various Pitches of Threads. By Oscar E. Perrigo. Cloth, 8x6 ins., 81 pp., illus. New York. The Derry-Collard Company, 1903. $1.00.

Some time ago the author had occasion to make an examination of the subject of change gears for engine lathes and the development of the devices for this purpose, as represented by the existing patents which have been granted for the same. The result of this study is now published so that it may serve as a book of reference. Most of the matter has been published in the columns of *Machinery*. There were one hundred and sixty-four patents examined, and out of this mass, twenty-nine were selected as bearing directly upon the change gear problem, the others being for forms of variable speed devices and similar inventions, not properly coming under the head of the evolution of the change gear. These twenty-nine patents have been described, their special or distinguishing features illustrated and compared in a manner which, it is hoped, will be useful to those who may be interested in this field of mechanical development. There is an index of three pages.

FREE-HAND LETTERING.

Being a Treatise on Plain Lettering from the Practical Standpoint for Use in Engineering Schools and Colleges. By Victor T. Wilson. Cloth, 9x6 ins., 10+95 pp., 23 plates. New York, John Wiley & Sons, 1903. $1.00.

The author's object is to cultivate the conception that all lettering is design, that any mathematical or mechanical attempt at treatment is entirely impracticable in ordinary work. Emphasis is laid upon attaining facility in the free single-stroke letter used on working drawings, by a careful analysis of the stroking and by practical points about the handling of a pen and a description and an illustration of a variety of styles from which to choose. The chapter upon the design of letters, which it is hoped, will afford matter of interest to the student, is not intended to form part of a regular course of study, but is for occasional reference only. Footnotes have been added to a number of the plates, summarizing the chief points to be noted about them, also references are printed under each plate, covering all the places in which each is discussed in the text. The Contents are: The Construction of Roman and Gothic Letters; Spacing; The Use of the Pen and Off-hand Lettering: Design of Lines and of Titles; Lettering for Various Technical Purposes, Including Photo-reproduction; The Design of Lettering; Mechanical Aids to Lettering.

MACHINE DESIGN.

Part I. Fastenings. By William Ledyard Cathcart. Cloth, 9x6 ins., 11+291 pp., illus. New York, D. Van Nostrand Company, 1903. $3.00.

The preface states that the main purpose of this book is to present, in compact form for the use of the student and designer, modern American data from the best practice in the branch of Machine Design, to which the work refers. The theoretical treatment of the subject has also been given; but this has been done for completeness only, since that field, the author believes, has been covered by able writers. The chapter headings are: Shrinkage and Pressure Joints; Screw Fastenings; Riveted Joints: Theory and Formulæ; Riveted Joints: Tests and Data from Practice; Keyed Joints; Pin Joints. There is an index of five pages.

AN ELEMENTARY COURSE IN THE INTEGRAL CALCULUS.

By Daniel Alexander Murray. Cloth, 8 x 6 ins., 14+288 pp., New York, Cincinnati, Chicago, American Book Company. $2.00.

The Contents are: Integration, a Process of Summation; Integration, the Inverse of Differentiation; Fundamental Rules and Methods of Integration; Geometrical Applica-

* Unless otherwise specified books in this list have been donated to the Library by the publishers.

tions of the Calculus; Rational Fractions; Irrational Functions; Integrations of Trigonometric and Exponential Functions; Successive Integration; Multiple Integrals; Further Geometrical Applications; Mean Values; Applications to Mechanics; Approximate Integration; Integration by Means of Series; Integration by Means of the Measurement of Areas; Integral Curves; Ordinary Differential Equations; Appendix. There is an index of five pages.

DIFFERENTIAL AND INTEGRAL CALCULUS.

By Virgil Snyder and John Irwin Hutchinson. Cloth, 8 x 6 ins., 16+320 pp. New York, Cincinnati, Chicago, American Book Company. $2.00.

The Contents are: Fundamental Principles; Differentiation of the Elementary Forms; Successive Differentiation; Expansion of Functions; Intermediate Forms; Mode of Variation of Functions of One Variable; Rates and Differentials; Differentiation of Functions of Two Variables; Change of the Variable; Tangents and Normals; Polar Coördinates; Derivative of an Arc, Area, Volume and Surface of Revolution; Asymptotes; Determination of Asymptotes; Direction of Bending; Points of Inflexion; Contact and Curvature; Evolutes and Involutes; Singular Points; Envelopes; General Principles of Integration; Reduction Formulas; Integration of Rational Fractions; Integrations by Rationalization; Integration of Trigonometric and other Transcendental Functions; Integration as a Summation; Geometrical Applications; Successive Integration. There is an index of two pages.

ELEMENTS OF THE DIFFERENTIAL CALCULUS.

By James McMahon and Virgil Snyder. Cloth, 8 x 6 ins., 14+337 pp. New York, Cincinnati, Chicago, American Book Company. $2.00.

The Contents are: Fundamental Principles; Differentiation of the Elementary Forms; Successive Differentiation; Expansion of Functions; Intermediate Forms; Mode of Variation of Functions of One Variable; Rates and Differentials; Determination of Functions of More than One Variable; Successive Partial Differentiation; Maxima and Minima of Functions of Two Variables; Change of the Variable; Tangents and Normals; Derivative of an Arc, Area, Volume and Surface of Revolution; Asymptotes; Direction of Bending; Points of Inflexion; Contact and Curvature; Evolutes and Involutes; Singular Points; Curve Tracing; Envelopes. There is an index of two pages.

Gifts have also been received from the following:

Allen, Kenneth. 1 pam.
Am. Soc. Mech. Engrs. 1 bound vol.
Arango, R. M. 1 pam.
Ariz.—Agri. Exper. Station. 1 pam.
Boecklin, Werner, 1 pam.
Bond, E. A. 2 bound vol.
Boston, Mass.—Pub. Lib. 1 vol.
British Fire Prevention Comm. 42 pam.
Buffalo, N. Y.—Bureau of Water. 1 pam.
Cambridge, Mass.—Water Board. 1 pam.
Carnegie Inst. 1 pam.
Colo.—Agri. Exper. Station. 2 pam.
Conn.—R. R. Commrs. 1 bound vol.
Fisher, Edwin A. 1 pam.
Fisk, W. L. 3 maps.
Fletcher, Robert. 1 vol.
Gaudard, J. 2 pam.
Geographical Soc. of Philadelphia. 1 pam.
Great Britain—Patent Office. 6 pam.
Harrod, B. M. 6 pam.
Heyland, Alexander. 1 pam.
Humphreys, David C. 1 bound vol.
Inst. of Civ. Engrs. 2 pam.
Ludlow, Henry H. 1 pam.
McGill, Grafton L. 1 pam.
Md.—Geol. Surv. 1 pam.
Mass.—Harbor and Land Commrs. 1 bound vol.
Mass.—State Board of Health. 1 bound vol.
Metropolitan Ry. Co. 1 pam.
New South Wales—Ry. Commrs. 1 pam.
Nichols, Charles H. 1 bound vol.
Nicholson, G. B. 1 pam.
North, Edward P. 1 bound vol.
Philadelphia, Pa.—Mayor. 3 bound vol.
Philadelphia Commercial Museum. 17 pam.
Queensland—Harbours & Rivers Dept. 20 pam.
Royal Soc. of New South Wales. 1 bound vol.
San Francisco, Cal.—Board of Supervisors. 1 bound vol.
Soper, George A. 1 pam.
South Eastern Ry. Co. 2 pam.
Spearin & Preston. 1 bound vol.
Stone, Herbert E. 1 bound vol.
Tanner, J. H. 1 bound vol.
U. S. Bureau of Labor. 1 pam.
U. S. Bureau of Navigation. 1 vol.
U. S. Bureau of Yards and Docks. 1 pam.
U. S. Commr. of Education. 1 bound vol.
U. S. Corps of Engrs. 1 vol.
U. S. Director of the Census. 1 bound vol.
U. S. Naval Observatory. 1 pam.
U. S. Weather Bureau. 2 bound vol.
Univ. of Pa. 1 pam.
Value, B. R. 1 pam.
Waddell, Montgomery. 1 pam., 2 vol.
Worcester Polytechnic Inst. 1 pam.

BY PURCHASE.

The Dynamo: Its Theory, Design, and Manufacture. By C. C. Hawkins and F. Wallis. Third Edition, Revised and Enlarged. New York, The Macmillan Co., 1903.

Electric Traction. A Practical Handbook on the Application of Electricity as a Locomotive Power. By John Hall Rider. London, Whittaker & Co., New York, 1903.

Handbook of Electrical Laboratory and Testing Room. By J. A. Fleming. Vol. II. New York, D. Van Nostrand Company; London, "The Electrician" Printing and Publishing Company.

History of American Steam Navigation. By John H. Morrison. New York, W. F. Sametz & Co., Inc., 1903.

The Steam Turbine. By Robert M. Neilson. Second Edition, Revised and Enlarged. Longmans, Green, & Co., London, New York and Bombay, 1903.

Liquid Fuel and Its Combustion. By Wm. H. Booth. New York, E. P. Duton & Co., 1904.

Machine Design. Part II. Form, Strength, and Proportions of Parts. By Forrest R. Jones. Third Edition, Revised. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

Technical Mechanics. By Edward R. Maurer. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1903.

A Treatise on Friction and Lost Work in Machinery and Mill-work. By Robert H. Thurston. Seventh Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

Die Entwickelung des Niederrheinisch-Westfälischen Stein-kohlen-Bergbaues in der zweiten Hälfte des 19. Jahrhunderts. Herausgegeben vom Verein für die bergbaulichen Interessen im Oberbergamtsbezirk Dortmund in Gemeinschaft mit der Westfälischen Berggewerkschaftskasse und dem Rheinisch-Westfälischen Kohlensyndikat. Vol. 2–6. Berlin, Julius Springer, 1902–03.

Ore Dressing. By Robert H. Richards. 2 vol. New York and London, The Engineering and Mining Journal, 1903.

Infection and Immunity, with Special Reference to the Preven-tion of Infectious Diseases. By George M. Sternberg. G. P. Putnam's Sons, New York and London, 1903.

Industrial Uses of Water. By H. De La Coux. Translated from the French and Revised by Arthur Morris. London, Scott, Greenwood & Co.; New York, D. Van Nostrand Co., 1903.

SUMMARY OF ACCESSIONS.

January 13th to February 9th, 1904.

Donations (including 18 duplicates)................	158
By purchase..	18
Total..	176

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
BAIRD, HOWARD CARTER. Prin. Asst. Engr., Phœnix Iron Co., Phœnixville, Pa.	Jun.	June 6, 1893
	Assoc. M.	Oct. 5, 1898
	M.	Feb. 2, 1904
HEWES, VIRGIL HENRY. Care, Lewinson & Just, 128 West 42d St., New York City		Feb. 3, 1904
HUBBELL, CLARENCE WILLIAM, Civ. Engr. to Board of Water Commrs., 232 Jefferson Ave., Detroit, Mich.	Jun.	May 31, 1898
	Assoc. M.	April 4, 1900
	M.	Jan. 5, 1904
LYON, HENRY LLOYD. Deputy Water Commr., Municipal Bldg., Buffalo, N. Y.		Feb. 3, 1904
MILLER, RUDOLPH PHILIP. 141 East 40th St., New York City	Jun.	Jan. 2, 1890
	Assoc. M.	April 7, 1897
	M.	Jan. 5, 1904
ROSS, FLORIAN GAIB. Farmers Bank Bldg., Pittsburg, Pa.		Dec. 2, 1903
SLEEPER, GEORGE EDWARD. P. O. Box 3198, Boston, Mass.		Feb. 3, 1904
SOUDER, HARRISON. 4435 Sansom St., Philadelphia, Pa		Jan. 6, 1904
THOMSON, REGINALD HEBER. City Engr., 701 Yesler Way, Seattle, Wash.		Dec. 2, 1903
ZINN, GEORGE ARTHUR. Maj., Corps of Engrs., U. S. A., U. S. Engr. Office, Wheeling, W. Va.		Feb. 3, 1904

ASSOCIATE MEMBERS.

ADGATE, FREDERICK WHITNEY. Supt. for Foundation & Contr. Co,, Omaha, Nebr		Jan. 6, 1904
BOARDMAN, HAROLD SHERBURNE. Assoc. Prof. of Civ. Eng., Univ. of Maine, Orono, Me		Feb. 3, 1904
BURROWES, HARRY GILBERT. Res. Engr., Atlantic Ave. Impvt., L. I. R. R., 5 Hanson Pl., Brooklyn, N. Y.	Jun.	Sept. 2, 1902
	Assoc. M.	Feb. 3, 1904
CLARK, EDWARD COTMAN. (Swinburne & Clark), 156 Fifth Ave., New York City		Feb. 3, 1904
CUMMINGS, NOAH. Asst. Engr., Dept. of Bridges, 213 West 136th St., New York City	Jun.	Mar. 3, 1896
	Assoc. M.	Jan. 6, 1904
DOWNES, ALFRED KIMBALL. 71 Broadway, New York City		Feb. 3, 1904
FULLER, ANDREW DANIEL. Cons. and Contr. Engr., 3 Hamilton Pl., Boston, Mass.	Jun.	Dec. 6, 1898
	Assoc. M.	Jan. 6, 1904
FULLER, CARL HAMILTON. L. Schreiber & Sons Co. (Res., 3606 Bevis Ave., Station H), Cincinnati, Ohio	Jun.	Mar. 5, 1901
	Assoc. M.	Feb. 3, 1904
KELLY, WILLIAM. 1st Lieut., Corps of Engrs., U. S. A., U. S. Engr. Office, New London, Conn.		Feb. 3, 1904
MERRILL, OGDEN. 78 South 10th St., Brooklyn, N. Y.		Feb. 3, 1904
RAINBOW, JOHN ROWORTH. 42 West 26th St., New York City.		Jan. 6, 1904

		Date of Membership.
ROUNDEY, EUGENE PERONNEAU. Asst. Hydrographer, U. S. Geological Survey, 39 West St., Utica, N. Y		Jan. 6, 1904
SMITH, EDGAR MAVERICK. Engr., Ry. Appliances Co., 1175 Old Colony Bldg., Chicago, Ill		Dec. 2, 1903
THOMSON, ALEXANDER, Jr. Asst. Engr., Rapid Transit Comm., 4 Court Sq. (Res. 351a Quincy St.), Brooklyn, N. Y	Jun. Assoc. M.	Dec. 4, 1900 Feb. 3, 1904
VINTON, THOMAS MACINTIRE. Secy. and Treas., Tucker & Vinton, 156 Fifth Ave., New York City		Feb. 3, 1904

ASSOCIATES.

GOLDING, JOHN FRENCH. Pres., Expanded Metal Eng. Co., 256 Broadway, New York City	Feb. 3, 1904

JUNIORS.

ANTHONY, WALTER LORING. Care, R. H. Tingley Co., 75 Westminster St., Providence, R. I.	Jan. 5, 1904
FISCHER, GUILLERMO GUSTAVO. 1534 I St., N. W., Washington, D. C	Feb. 2, 1904
HOWES, RALPH HOLT. 36 East 28th St., New York City	Feb. 2, 1904
LEAKE, BOUDINOT GAGE. Gen. Office, C., R. I. & G. Ry., Fort Worth, Tex	Jan. 5, 1904
PLOGSTED, WALTER JOHN. Yale, Okla	Oct. 6, 1903
SAYERS, EDWARD LAWRENCE. Care, P., N. Y. & L. I. R. R., 20 West 34th St., New York City	Feb. 2, 1904
TUNSTALL, WHITMELL PUGH. Care, Div. Engr., M. of W., B. & O. R. R., Cleveland, Ohio	Oct. 6, 1903
WALTERS, HENRY RADCLYFFE ST. ARVANS. Engr. and Chf. Draftsman, The Guerber Eng. Co. (211 S. New St.), Bethlehem, Pa	Oct. 6, 1903

RESIGNATIONS.

	Date of Resignation.
JACKSON, ROSCOE BRADBURY	Dec. 31, 1903
NAYLOR, EZRA BOOTH	Dec. 31, 1903

DEATHS.

DEFOREST, GEORGE THOMPSON.....Elected Associate Member, December 4th, 1895; died July 25, 1901.

ROSENZWEIG, ALFRED.............Elected Junior, June 7th, 1882; Member, January 4th, 1893; died January 13th, 1904.

SMITH, BENJAMIN BURGH......... Elected Member, November 7th, 1888; died February 7th, 1904.

TAYLOR, SELWYN MELLON.........Elected Member, October 7th, 1903; died January 25th, 1904.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(January 13th to February 8th, 1904.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City. 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.

LIST OF ARTICLES.

Bridge.

Deflections of Beams with Variable Moments of Inertia. C. W. Hudson, M. Am. Soc. C. E. (54) Vol. 51.
Loadings for Railroad Bridges. An Informal Discussion. (54) Vol. 51.
The Assimilation of Railway Practice in Respect of Loads on Bridges up to 200 Feet Span. Alexander Ross, M. Inst. C. E. (63) Sup., Vol. 154.
An Unusual Bridge Accident.* (13) Jan. 14.
Reinforced Concrete Arch Bridge over the Yellowstone River, Yellowstone National Park.* H. M. Chittenden. (13) Jan. 14.
Details of the Williamsburg Bridge Towers.* (14) Jan. 16.
A French Cantilever Bridge without a Suspended Span. (14) Jan. 16.
Proposed Reconstruction of the Brooklyn Bridge.* (Report by Gustav Lindenthal.) (19) Jan. 16.
The Point Bridge at Pittsburg, Pa., Which Must Be Rebuilt.* (13) Jan. 21.
Concrete Arch Bridge with Spandril Relieving Arches.* (12) Jan. 22.
The Manhattan Bridge across the East River.* (46) Jan. 23.
The New Stone Arch Bridge of 295 Ft. Span at Plauen, Saxony.* (13) Jan. 28.
The Des Moines River Viaduct of the Chicago Great Western Railway.* (14) Serial beginning Jan. 30.
Types of Concrete Steel Arch Bridges. Daniel B. Luten. (Paper read before the Indiana Eng. Soc.) (18) Jan. 30.
Construction of the Globe Island Bridge, Sydney, New South Wales.* John Plummer. (19) Feb. 6.
Strain Sheet and Specifications for a Four-Truss Double-Deck Railroad Bridge.* (14) Feb. 6.
Le Pont Troitsky sur la Néva à Saint Petersbourg.* P. Bodin. (33) Jan. 23.

Electrical.

Wireless Telegraphy. Edmund A. N. Pochin. (63) Sup., Vol. 154.
Transmission and Distribution by Single-phase Alternating Current. E. W. Monkhouse, M. Inst. C. E. (63) Sup., Vol. 154.
A Graphic Recording Ammeter.* A. H. Armstrong. (42) Nov.
The Comparative Behavior of Floating and Booster-Controlled Batteries on Fluctuating Loads.* Lamar Lyndon. (42) Nov.
The Electrical Conductivity of Commercial Copper.* Lawrence Addicks. (42) Nov.
Electricity in the Bottle Industry.* R. M. Hopkins. (69) Jan.
Stepney Borough Council Electricity Works.* (73) Jan. 8.
The Albion System of Magneto Ignition for Internal Combustion Engines.* (73) Jan. 8.
The Localization of Breaks in Submarine Cables. (26) Jan. 8.
A Rolling Mill Directly Driven by Electric Motors. (13) Jan. 14.
A New Potentiometer. W. Clark Fisher. (73) Jan. 15.
An Emergency or Master Switch for Central Stations. W. M. Thornton. (73) Jan. 15.
Swindon Corporation Electricity Supply Works.* (26) Jan. 15.
Electricity in a Cotton Mill.* (26) Jan. 15.
Testing Large Alternators. W. E. Burnand. (73) Jan. 15.
A Critical Review of Electrostriction. Louis T. More. (27) Jan. 16.
Blockmann Radio-Telegraph System.* A. Frederick Collins. (27) Jan. 16.
Measurement of Current by Copper Voltameter. J. L. Dickson. (27) Jan. 16.
Single-Phase Condenser Motor.* (27) Jan. 16.
The Grounded Neutral. R. S. Hale. (27) Jan. 16; (24) Jan. 25.
The De Forest Wireless Tests across the Irish Channel.* (46) Jan. 16.
The Lorimer Automatic Telephone System.* (27) Jan. 16.
The Use of Concrete Blocks in Manhole Construction.* Hugh C. Baker, Jr. (13) Jan. 21.
Lamme's Single-Phase Motor Patent. (73) Jan. 22.
Electric Power in Queensland Railway Workshops.* (73) Jan. 22.
On the Magnetic Dispersion in Induction Motors, and Its Influence on the Design of These Machines. Hans Behn-Eschenburg. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Serial beginning Jan. 22.
Three-Phase Working with Special Reference to the Dublin System.* William Drew. (Paper read before the Inst. of Elec. Engrs.) (73) Serial beginning Jan. 22.
The Transformation of Thermochemical Energy into Voltaic Energy or Electromotive Force. D. Tommasi. (26) Jan. 22.
A Method of Photographing Alternating-Current Wave Form.* C. J. Spencer. (27) Jan. 23.
Coal Consumption in Central Stations. Alfred S. Giles. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Jan. 22; (47) Jan. 23.
The Choice of Air Gap Diameter for Induction Motors. H. M. Hobart. (27) Jan. 23.
The Electric Drive as Applied in a Modern Machine Shop.* (27) Jan. 23.
The New Automatic Telephone Exchange at Grand Rapids, Mich.* Edward J. Hart. (27) Jan. 23.
Electrical Foucault Pendulum Systems.* Ernest K. Adams. (27) Jan. 30.
Electric Heating Equipment of a Modern Hat Factory.* Max Loewenthal. (27) Jan. 30.
Electric Pumping Plant at Mobile, Ala.* (14) Jan. 30.

* Illustrated.

Electrical—(Continued).

The Theoretical Determination of Power Curves. William J. Berry. (27) Jan. 30.
Hookham's Prepayment Electricity Meter.* (47) Jan. 30.
The Siskiyou Power Transmission.* (27) Jan. 30.
The Individual Application of Electric Motors to Machinery, with Rules for Determining the Size of Motors. William Cooper. (10) Feb.
Construction and Maintenance of Electric Wires. (Abstract of Paper read before the Amer. Soc. of Mun. Improvements.) (60) Feb.
Some Electrically Operated Cranes for Railway and Harbor Work.* Frank C. Perkins. (41) Feb.
Portable Electric Drilling and Riveting Machines.* Frank C. Perkins. (10) Feb.

Marine.

Drilled *versus* Punched Rivet-Holes in the Hulls of Steel Ships. A. F. Yarrow, M. Inst. C. E. (63) Sup., Vol. 154.
Screw-Shafts. John List, M. Inst. C. E. (63) Sup., Vol. 154.
Marine Propellers with Non-Reversible Engines and Internal-Combustion Engines.* Rankin Kennedy. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Jan. 9.
The Chilian Battle-ship *Libertad*.* (11) Jan. 15.
A New Method of Coaling War Vessels at Sea. (13) Jan. 21.
An Air Valve for Regulating the Time of Passing through an Air Lock; Used in the Kiel Dry-Dock Construction.* (13) Jan. 21.
New Japanese Armored Cruisers *Kasaga* and *Niasin*.* (46) Jan. 23.
The Mietz & Weiss Two-Cylinder Marine Kerosene Engine.* (20) Jan. 28.
Frenchman's Bay Coaling Plant.* (14) Jan. 30.
Attaque et Défense des Cotes au Moyen des Torpilles.* H. Noalhat. (36) Serial beginning Jan. 10.

Mechanical.

Tests of the Efficiency of Hoisting Tackle. S. P. Mitchell, M. Am. Soc. C. E. (54) Vol. 51.
Theory of Centrifugal Pumps and Fans: Analysis of Their Action, with Suggestions for Designs.* Elmo G. Harris, M. Am. Soc. C. E. (54) Vol. 51.
Internal-Combustion Engines for Driving Dynamos. Herbert A. Humphrey, M. Inst. C. E. (63) Sup., Vol. 154.
Speeds of Overhead and Other Cranes for the Economic Handling of Material. Archibald Potter Head, M. Inst. C. E. (63) Sup., Vol. 154.
Steam Turbines. Prof. Rateau. (63) Sup., Vol. 154.
The Use of Petrol Motors for Locomotion. E. Sauvage. (63) Sup., Vol. 154.
Mechanical Draft. J. J. Brown, M. Am. Soc. M. E. (69) Nov.
Modern Fuel Economy. George E. Walsh. (69) Nov.
The Drive of Machine Tools.* Charles W. Startsman. (69) Nov.
The Condenser.* J. J. Brown, M. Am. Soc. M. E. (69) Dec.
The Modern Economic Factory Light. Fred R. Davis. (69) Dec.
Improved Mechanical Stoking. (60) Jan.
The Evolution of the Rotary Kiln. Benton G. Boilleau and C. W. Lyon. (67) Jan.
The Harrisburg Engine System.* (69) Jan.
The Steam Superheater.* John Primrose. (69) Jan.
The Siemens Electrical Pyrometer.* (22) Jan 1.
A Modern American Foundry.* (12) Jan. 8.
Coal Screening and Washing Plant at a German Colliery.* (57) Jan. 8; (22) Jan. 8.
Merchant Bar Mill of the International Harvester Company.* (22) Jan. 8.
The Design of Steam Turbine Discs. Frank Foster. (12) Jan. 8.
The Vogt Gas-Engine.* Herbert A. Humphrey, M. Inst. C. E., M. I. Mech. E. (11) Jan. 8.
Steel Castings.* Arthur Simonson. (47) Jan. 9.
The Design of Speed Cones, Gears, &c., for Machine Tools; To Give Speeds in Geometrical Progression. W. Owen. (47) Jan. 9.
A Two-Cylinder Portable Steam or Air Motor.* (20) Jan. 14.
Brick Making Plant of the Western Brick Co., Danville, Ill.* (13) Jan. 14.
Coal and Ash Handling Plant of the New York Rapid Transit Power House.* (13) Jan. 14.
The Brown & Sharpe No. 2-A Universal Milling Machine, Motor Driven.* (20) Jan. 14.
Traveling Inverted Pillar Crane.* (12) Jan. 15.
A New Centrifugal Pump for High Lifts.* (19) Jan. 16.
The Barton 150-Horsepower Airship's Forthcoming Trial Trip.* (46) Jan. 16.
The Production of Gas for Gas Engines * (17) Jan. 16.
Cable Haulage for Transporting Marl to the Mills of the Bronson Portland Cement Co.* (13) Jan. 21.
The Adriance New Style Drawing Press.* (20) Jan. 21.
The Pilling Air Engine and Hoist.* (20) Jan. 21.
Two New Machine Tools for Working Steel Plate and Structural Shapes.* (13) Jan. 21.
Notes on the Design of Rolls.* Emil Kirchberg. (From *Stahl und Eisen*.) (22) Jan. 22.
Coal Consumption in Central Stations. Alfred S. Giles. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Jan. 22; (47) Jan. 23.

* Illustrated.

Mechanical—(Continued).

The Cincinnati Gear Compressor for the St. Louis Exposition.* (14) Jan. 28; (20) Jan. 21.
Air Compressors for St. Louis Exposition.* (18) Jan. 28.
Compressed Air Plant, St. Louis Exposition.* (40) Jan. 28.
Design for a Gasoline Motor.* J. C. Brocksmith. (47) Jan. 28.
High-Power Westinghouse-Parsons Steam Turbines.* (40) Jan. 28.
The Electric Drive as Applied in a Modern Machine Shop.* (27) Jan. 28.
A New Source of Economy for Gas Works: Firebrick Making at the Crystal Palace District Gas Company's Works.* (24) Jan. 25.
The Economic Admission of Steam to Water Gas Producers of the Lowe Type. G. W. M'Kee. (Paper read before the Soc. of Chemical Industry.) (24) Jan. 25.
A New Charcoal Retort Plant.* Ernst A. Sjöstedt. (20) Jan. 28.
A Substitute for Looped Hose on Traveling Air Hoists.* (20) Jan. 28.
Alteration of Fire-Brick by Furnace-Gases.* (62) Jan. 28.
Cheap Hoisting Appliance.* (62) Jan. 28.
Smoke Prevention. R. P. King. (Abstract of Paper read before the Indiana Eng. Soc.) (13) Jan. 28.
The Norton New 14-Foot Grinding Machine.* (20) Jan 28.
The Sand-Lime Brick Industry in this Country.* (20) Jan. 28.
Automobiles.* (46) Jan. 30.
Electric Pumping Plant at Mobile, Ala.* (14) Jan. 30.
Frenchman's Bay Coaling Plant.* (14) Jan. 30.
High-Pressure Gas Distribution by Gas Power. (14) Jan. 30.
Mond Gas.* A. Humboldt Sexton. (47) Jan. 30.
The Edison Portland Cement Works.* (19) Serial beginning Jan. 30.
The Paris Automobile Show.* (19) Serial beginning Jan. 30.
Crossley's Gas Producer for Bituminous Coal.* (64) Feb.
High-Power Steam Turbines.* (41) Feb.; (64) Feb.
Line of Progress in the Efficiency of the Combustion Motor.* Edward C. Warren. (9) Feb.
Mechanical and Commercial Aspects of the Alcohol Motor.* Henri Dupays. (9) Feb.
Motor-Driven Machine Tools; Planer Driving by Electric Motors.* (25) Feb.
The Hebb Coke-Drawing Machine.* (45) Feb.
The Mackinac Blowing Engine at the Calumet and Hecla Mines.* Joseph S. Soddy. (64) Feb.
The Power Plant and Mechanical Equipment of Apartment Houses. Percival Robert Moses. (9) Feb.
Cockerill Gas Engines.* Emile Guarini. (64) Feb.
A Remarkable High-Speed Four-Valve Engine.* (64) Feb.
Utilization of Sulphur in Gas Works. (24) Feb. 1.
A Sectional Multiple Block Wire Bench.* (20) Feb. 4.
A Very Large Automatic Gear Cutting Machine. (20) Feb. 4.
Special Machine Tools at the Corliss Shops.* (20) Feb. 4.
Specifications for an Acetylene Gas Generating Apparatus for Fort McPherson, Ga. (13) Feb. 4.
The Deschamps Down Draft Gas Producer.* (20) Feb. 4.
The Perkins Air Cooled Cylinder Gas Engine.* (20) Feb. 4.
The Manufacture of Welded Pipe.* Victor Beutner. (20) Serial beginning Feb. 4.
A Foundry Floor Crane.* (40) Feb. 5.
Gas Engines in Railroad Work. (15) Feb. 5.
Steam Plant of the Tileston & Hollingsworth Company.* (14) Feb. 6.
The New Henry R. Worthington Hydraulic Works at Harrison, N. J.* (14) Serial beginning Feb. 6.
The Power Equipment of the Sackett & Wilhelms Lithographing & Printing Company.* (14) Serial beginning Feb. 6.
The Didier-Stettiner System of Inclined Retorts in England.* (24) Serial beginning Feb. 8.
Transporteur Aérien et Grues de Déchargement de l'Usine Métallurgique d'Elba.* E. Boucher. (33) Jan. 9.
Les Moteurs a Gaz Pauvre. A. Abraham. (36) Serial beginning Jan. 10.
Les Progrès de l'Automobilisme en 1903.* F. Drouin. (33) Serial beginning Jan. 16.

Metallurgical.

Alloys of Iron, Manganese and Nickel. R. A. Hadfield, M. Inst. C. E. (63) Sup., Vol. 154.
The Dangerous Crystallization of Mild Steel and Wrought Iron.* J. O. Arnold. (63) Sup., Vol. 154.
The Continuous Production of Open-Hearth Steel from Molten Blast-Furnace Metal. Benjamin Talbot. (63) Sup., Vol. 154.
The Equalization of Hot-Blast Temperatures for Blast-Furnaces.* Joseph Hutchinson Harrison, M. Inst. C. E. (63) Sup., Vol. 154.
Notes on the Metallurgy of Copper of Montana. H. O. Hofman. (7) Dec.
Ore Dressing or the Mechanical Preparation of Ores. Robert H. Richards. (7) Dec.
The Physical Structure of Metals and Alloys.* J. J. Kessler, Jr. (Abstract of Paper read before the Engineers' Club of St. Louis.) (1) Dec.

* Illustrated.

Metallurgical—(Continued).

Side Blow Converters. N. Lilienberg. (Paper read before the Philadelphia Foundrymen's Assoc.) (20) Jan. 14.
The Electric Smelting of Iron and Steel.* (22) Jan. 15.
Thermit: Its Value in Motive Power Repairs. (18) Jan. 16.
Hearth Area and the Number of Tuyeres in Blast Furnace Practice. (62) Jan. 21.
The Delprat or Salt-Cake Process for Mixed Sulphides. Donald Clark. (16) Jan. 21.
Sixth Report to the Alloys Research Committee on the Heat Treatment of Steel. (Read before the Inst. Mech. Engrs.) (11) Serial beginning Jan. 22; abstract (12) Jan. 22.
The Heat Treatment of Steel.* Wm. C. Roberts-Austen and William Gowland. (47) Serial beginning Jan. 23.
Improvements in Cyanidation. Alfred James. (16) Jan. 28.
The Platz Method of Calculating Furnace Burdens. J. B. Nau. (20) Jan. 28.
Magnetic Alloys of Unmagnetic Metals. (20) Jan. 28.
A New Reheating Furnace.* (20) Jan. 28.
Notes on Cupolas and Cast Iron. C. Morehead. (Abstract of Paper read before the Rugby Eng. Soc.) (47) Jan. 30.
Recent Investigations and Discoveries in Cast Iron.* Alexander E. Outerbridge, Jr. (3) Feb.
Steel Castings. I. L. Knox. (62) Feb. 4.
The Baby Bessemer Works and Their Costs. Ludwig Unckenbolt. (From *Stahl und Eisen*.) (62) Feb. 4.
Light Aluminum Alloys. (19) Feb. 6.

Mining.

Percussion Coal-Cutters. Sir Thomas Wrightson, M. Inst. C. E., and John Morison, M. Inst. C. E. (63) Sup., Vol. 154.
Coal Screening and Washing Plant at a German Colliery.* (57) Jan. 8; (22) Jan. 8.
Gold Dredging.* F. Winter Taylor. (16) Jan. 14.
Experimental Galleries for Testing Explosives in Germany and Belgium.* (57) Jan. 15.
Iron Shaft Fittings with Cage Guides on One Side.* F. Schulte. (57) Jan. 15.
Aerial Tramways as an Economic Means of Transportation.* Stephen de Zombory. (Paper read before the Transcontinental Min. Cong.) (19) Jan. 16.
Testing Caps or Detonators in the Laboratory.* A. W. Warwick. (45) Feb.
The Spraying or Watering Problems. James Ashworth. (45) Feb.
Mine Ventilation. W. J. Mollison. (Paper read before the Central Min. Inst. of Western Pennsylvania.) (45) Feb.
Mechanical Devices at Coal Mines.* L. L. Logan. (Paper read before the Central Min. Inst. of Western Pennsylvania.) (45) Feb.
Testing Explosives in Germany and Belgium.* (62) Feb. 4.

Miscellaneous.

The Metric System. Charles. F. Hauss. (70) Jan.
Caisson Disease and a Safety Apparatus for Pneumatic Caisson Locks.* (14) Jan. 23.

Municipal.

An Example of Thin Macadam Road Construction along the Charles River, Mass.* J. Albert Holmes. (13) Jan. 14.
Philadelphia's New Fire Fighting Service.* (20) Jan. 21.
Making Cement Roadways in Richmond, Ind. H. L. Weber. (13) Jan. 28.
Paving Brick for Street Railway Track.* (13) Jan. 28.
The Bitulithic Pavement. W. A. Hoyt. (Abstract of Paper read before the Mich. Eng. Soc.) (60) Feb.
Concrete Foundations and Cement Filler for Brick Pavements: A Comparison of Natural Cements and Portland. O. L. Gearheart. (Abstract of Paper read before the Ill. Soc. of Engrs. and Surveyors.) (13) Feb. 4.
Goudronnage de Chaussées dans le Département de Seine-et-Marne. (43) 2e Trimestre, 1903.
Suppression de la Poussière des Chaussées Empierrées par le Goudronnage et l'Emploi d'Enduits Collants. M. Le Gavrian. (43) 2e Trimestre, 1903.
Goudronnage et Petrolage des Routes. J. Feugeres. (35) Serial beginning Jan.

Railroad.

Some Railway Construction in Oklahoma.* A. G. Allan, Assoc. M. Am. Soc. C. E. (54) Vol. 51.
High-Speed Electric Traction on Railways.* J. W. Jacomb-Hood, M. Inst. C. E. (63) Sup., Vol. 154.
Automatic Signalling.* William John Cudworth, M. Inst. C. E. (63) Sup., Vol. 154.
The Design of Permanent-Way and Locomotives for High Speeds. James Charles Inglis, M. Inst. C. E. (63) Sup., Vol. 154.

* Illustrated.

Railroad—(Continued).

Design and Operation of Division and Tide-Water Terminals.* C. L. Bardo. (65) Dec.
Duplex Valve Gear, London and North-Western Railway.* (12) Jan. 8.
Electrification of the Liverpool, Southport and Crossens Section of the Lancashire and Yorkshire Railway.* (11) Jan. 8; (17) Jan. 30.
Prussian State Railway Locomotives. (Abstracts from the Specifications of the Prussian State Railways.) (11) Jan. 8.
Steam Motor-Car for the Taff Vale Railway.* (11) Jan. 8.
Atlantic Type Passenger Locomotive for the North-Eastern Railway.* (47) Jan. 9.
A New Interlocking Machine; the Pneumatic Signal Co.'s All-Electric Machine.* (13) Jan. 14.
Track Plans for the Washington Union Station.* (15) Jan. 15.
Seaboard Air Line Shops at Portsmouth, Va.* (40) Jan. 15.
Locomotive Operation: A Technical and Practical Analysis.* G. R. Henderson, M. Am. Soc. M. E. (40) Jan. 15.
New Express Engines North-Eastern Railway.* (12) Jan. 15.
The Ventilation of Some Continental Tunnels.* (12) Serial beginning Jan. 15.
Installation of a Coughlin-Sanford Swing-Rail Frog and Switch Point Lock on the I. C. R. R.* (18) Jan. 16.
The Pennsylvania Tunnel at New York City.* (46) Jan. 16.
Locomotive Counterbalancing.* (47) Jan. 16.
Notes on Early Canadian Transcontinental Railway Projects. (13) Jan. 21.
A Complete Journal Box.* (18) Jan. 23; (40) Jan. 22.
British Locomotive Work in 1903. Charles Rous-Marten. (12) Jan. 22.
Compound Goods Locomotive, Saxony State Railways.* (12) Serial beginning Jan. 22.
The Scheinig-Hofmann Shoe Rail-Joints.* (11) Jan. 22.
Locomotives for the Cape Government Railways.* H. W. Hanbury, Assoc. M. Inst. C. E. (11) Jan. 22.*
Telescopic Snow Sheds on the Central Pacific.* (15) Jan. 22.
Baldwin Four-Cylinder Balanced Compound Locomotives for the Santa Fé.* (15) Jan. 22.
Chesapeake & Ohio Eight-Wheel Switching Locomotive.* (40) Jan. 22.
Railroad Car Heating by Steam and Compressed Air.* (47) Jan. 23.
The Arnold Electro-Pneumatic Railway System.* B. J. Arnold. (47) Serial beginning Jan. 23.
Electrification of the Northeastern of England.* (40) Jan. 28.
Higher Braking Power for Freight Cars. Robert H. Blackall. (Paper read before the Railway Club of Pittsburg.) (18) Jan. 23.
Heavy Goods Engine for the Bengal-Nagpur Railway.* (19) Jan. 23.
The Pressure Retaining Valve: Its Value and Importance.* F. H. Parke. (15) Jan. 29.
Side-Bearing Trucks.* W. J. Knox. (40) Jan. 29.
Big Four Revision between Cincinnati and Sunman.* (40) Jan. 29.
Switching Locomotive for the Pennsylvania Lines.* (40) Jan. 29.
The Wabash Terminal at the World's Fair Grounds, St. Louis.* (15) Jan. 29.
Electrification of an English Steam Railway.* (27) Jan. 30.
Simple Consolidation Locomotive for N. Y. C. & H. R. R. R.* (18) Jan. 30.
An Important New Terminal-Yard Lighting and Power Plant, Weehawken, N. J.* (25) Serial beginning Feb.
A New 50-ton Box Car, with Structural Steel Underframe.* (25) Feb.
Coal Chutes for Locomotives.* (25) Feb.
Indicator Tests of a Large Tandem Compound, Atchison, Topeka & Santa Fé Railway.* (25) Feb.
Water Softening—Union Pacific Railway. (25) Feb.
Locomotives for Special Service on British Railways.* J. F. Gairns. (9) Feb.
Notes on Railroad Construction from the Resident Engineers' Standpoint. F. C. French, Assoc. M. Am. Soc. C. E. (Paper read before Iowa Eng. Soc.) (13) Feb. 4; (14) Serial beginning Jan. 30.
Flood Repairs to the Lehigh & Susquehanna Division of the Central Railroad of New Jersey.* M. A. Zook, M. Am. Soc. C. E. (13) Feb. 4.
An All Cast-Iron Turn-Table.* Jas. C. Bennett. (16) Feb. 4.
Steel Coke Car of Vanderbilt Design. (40) Feb. 5.
Grade Crossing Protection Between Steam and Electric Railways.* (40) Feb. 5.
The Maximum Economical Load for a Locomotive. C. T. Noyes. (Abstract of Paper read before the Pacific Coast Ry. Club.) (15) Feb. 5.
Consolidation Locomotive for the Central Railroad of New Jersey.* (40) Feb. 5.
Gas Engines in Railroad Work.* (15) Feb. 5.
Forty-Ton Coal Car with Steel Underframe.* (15) Feb. 5.
Indicateur-Enregistreur de Vitesse pour Locomotives: Système Flaman. A. Morizot. (34) Jan.
La Nouvelle Voiture Automobile à Vapeur du Chemin de Fer du Nord. Félix Sartiaux and J. Koechlin. (38) Jan.
Chauffage des Trains du Réseau de l'Est par la Vapeur et l'Air Comprimé Combinés.* H. Guerin. (33) Jan. 2.

* Illustrated.

Railroad—(Continued).

Frein à Vis, Système Schmid, Actionné par la Vide ou par l'Air Comprimé.* (33) Jan. 2.
Considérations sur l'Avenir de la Traction Électrique sur les Grandes Lignes de Chemins de Fer. R. Bonnin. (36) Serial beginning Jan. 10.

Railroad, Street.

The Position and Protection of the Third Rail on Electric Railways.* William E. Laugdon. (63) Sup., Vol. 154.
The Relative Advantages of Overhead, Deep-Level, and Shallow Subway Lines, for the Accommodation of Urban Railway Traffic. Stephen Butler Cottrell, M. Inst. C. E. (63) Sup., Vol. 154.
The Conditions Governing the Rise of Temperature of Electric Railway Motors in Service. Cary T. Hutchinson. (42) Nov.
A New Surface-Contact System for Electric Tramways.* (73) Jan. 8.
London County Council Tramways.* (73) Serial beginning Jan. 15.
The "G. B." Surface-Contact System.* (26) Jan. 15.
Freight and Express Cars for Brooklyn Rapid Transit. (40) Jan. 15.
A Modern Electric Railway Power Plant, Canandaigua, N. Y. (14) Jan. 16.
Electric Interurban in Western New York.* (17) Jan. 16.
Convertible Parlor and Sleeping Car for Electric Railways.* (18) Jan. 16.
Electric Power in Queensland Railway Workshops.* (73) Jan. 22.
Indianapolis and Northwestern Traction System.* (17) Jan. 23.
The Power House of the Interborough Rapid Transit Company, New York.* (14) Jan. 23: (17) Jan. 23.
Application of Single-Phase Alternating Current for Traction and Railway. B. G. Lamme. (19) Jan. 23.
Single-Phase Car Equipment at East Pittsburg.* (17) Jan. 23.
London's New Tube Railway.* C. H. Grinling. (15) Jan. 29.
New Chicago Union Traction Cars.* (17) Jan. 30.
Improvements in the Power Equipment of the Cleveland and Southwestern System.* (17) Jan. 30.
The Conneaut & Erie Interurban System.* (17) Feb. 6.
The Third-Rail Shoe on the Boston Elevated Railway.* (17) Feb. 6.
An Interesting Addition to Convertible Cars for the Washington Water Power Company.* (17) Feb. 6.
Storage Air Brake System in St. Louis.* (17) Feb. 6.
Water Tube Boilers in English Tramway Stations.* (17) Feb. 6.
The Electric Railway System of Vienna.* (17) Feb. 6.
St. Louis Transit Company's New Cars and Motors.* (17) Feb. 6.
Note sur l'Intérêt Qu'il y Aurait a Fixer Uniformément la Cote de Calage des Roues et le Mode d'Attelage de Tous les Véhicules Circulant sur les Voies de 1 Mètre.* M. Heude. (38) Jan.
Traction Électrique avec Moteurs Monophasés.* Emile Dieudonné. (36) Jan. 10.

Sanitary.

Sewage Purification. An Informal Discussion. (54) Vol. 51.
Bacterial Treatment of Water and Sewage. Percy Frankland. (63) Sup., Vol. 154.
Utility Exhaust Heating System.* (69) Nov.
Heating and Ventilating of Factories.* (69) Nov.
Description of Hot Water Heating Apparatus in the Schioldamn Institution, Copenhagen, Denmark.* A. B. Reck. (70) Jan.
Test of a Hot Air Heating Apparatus Using Radiators Instead of Registers.* Geo. M. Aylsworth. (70) Jan.
To Figure Heating Work Accurately—With a Table Showing the Losses in British Thermal Units for Various Surfaces. Chas. F. Hauss. (70) Jan.
Report on Garbage Collection and Disposal at St. Louis, Mo. (13) Jan. 14.
A System of Hot-Water Heating by the Use of Steam. (14) Jan. 16.
Steam Heating from a Central Station. F. B. Hofft. (Abstract of Paper read before the Indiana Eng. Soc.) (13) Jan. 21; (24) Feb. 1; (60) Feb.
The Use of Concrete Blocks in Manhole Construction.* Hugh C. Baker, Jr. (13) Jan. 21.
Caisson Disease and a Safety Apparatus for Pneumatic Caisson Locks.* (14) Jan. 23.
The Necessity of Moisture in Heated Houses. R. C. Carpenter. (Abstract of Paper the Amer. Soc. of Heating and Ventilating Engrs. (14) Jan. 23.
Heat Transmission Data for Calculating the Proportions of Heating Systems. (14) Jan. 23.
A Battery Furnace Residence Heating System.* C. E. Oldacre. (Abstract of Paper Presented to the Amer. Soc. of Heating and Ventilating Engrs.) (14) Jan. 30.
Rubbish Incineration in New York City, and the Design for the New Stanton Street Incinerator.* (14) Jan. 30.
Filters *versus* Contact Beds in Sewage Purification.* W. S. Shields. (Abstract of Paper read before the Indiana Eng. Soc.) (60) Feb.
The Wear of Sewer Inverts.* E. A. Hermann, M. Am. Soc. C. E. (13) Feb. 4.
Aération des Tunnels par Ventilation Mécanique: Systeme Saccardo. (35) Jan.

* Illustrated.

Structural.

The Fatigue of Cement Products. J. L. Van Ornum, M. Am. Soc. C. E. (54) Vol. 51.
An Investigation of the Properties of Brick, Under Different Physical Conditions.* Sherman M. Turrill, Assoc. Am. Soc. C. E. (54) Vol. 51.
Timber Tests. An Informal Discussion. (54) Vol. 51.
Impervious Concrete. An Informal Discussion. (54) Vol. 51.
Covering the Natick, Mass., Reservoir with a Concrete Roof.* Frank L. Fuller. (28) Dec.
The Protection of Steel from Corrosion. Charles L. Norton. (Extract from Rept. No. IX. of the Ins. Eng. Exp. Station.) (13) Jan. 14.
Graphical Determination of Angles in Skew Structural Work.* C. G. Wrentmore. (From the *Michigan Technic*, 1903.) (13) Jan. 14.
Supporting an Old Wall from a New Building.* (14) Jan. 16.
A Concrete-Steel Factory Building with Fifty-Two-Foot Roof Girders. (14) Jan. 16.
Some of the Causes of Recent Failures of Reinforced Concrete. Julius Kahn, Assoc. M. Am. Soc. C. E. (13) Jan. 21; (15) Jan. 22; (14) Jan. 23.
The Power House of the Interborough Rapid Transit Company, New York.* (14) Jan. 23; (17) Jan. 23.
The Cost of Raw Materials for Portland Cement Manufacture. Morris M. Green. (14) Jan. 23.
A Convenient Tie for Concrete Forms.* (13) Jan. 28.
The New Engineering Building of the University of Michigan. (18) Jan. 30.
Jacking Down Open Cribs for Underpinning.* (14) Jan. 30.
Concrete Building Blocks.* (14) Jan. 30.
Automatic Spacing of Rivet Holes.* (13) Feb. 4.
Efficiencies of Riveted Joints.* Gilbert S. Walker. (13) Feb. 4.
The New Henry R. Worthington Hydraulic Works at Harrison, N. J.* (14) Serial beginning Feb. 6.
The Kelly & Jones Company's Concrete-Steel Factory Building.* (14) Serial beginning Feb. 6.
Steel Roof Trusses in the New Union Railroad Station at Washington.* (14) Feb. 6.
More Light on the Theory of Concrete. Spencer B. Newberry. (Paper read before the Ind. Eng. Soc.) (14) Feb. 6.
Le Nouvel Hotel de Ville de Tours.* P. Leprince-Ringuet. (33) Jan. 9.
La "Maison des Chauteurs" à Strasbourg.* G. Espitallier. (33) Jan. 16.

Water Supply.

An Experimental Study of the Resistances to the Flow of Water in Pipes.* Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest H. Schoder, Jun. Am. Soc. C. E. (54) Vol. 51.
Automatic Modules for Regulating the Speed of Filtration.* Charles Anthony, Jr., M. A. M. Soc. C. E. (54) Vol. 51.
Steam Turbine Driven Centrifugal Pumps for High Lifts. Cecil West Darley, M. Inst. C. E. (63) Sup., Vol. 154.
Raising Water by Compressed Air. Percy Griffith, M. Inst. C. E. (63) Sup., Vol. 154.
Pumping by Electricity.* F. H. Pitcher. (28) Dec.
The Water Supplies of Southeastern Alaska. Ellen H. Richards. (7) Dec.
Covering the Natick, Mass., Reservoir with a Concrete Roof. Frank L. Fuller. (28) Dec.
Notes on the Water Supplies in the Black Hills of South Dakota and Vicinity. Ellen H. Richards. (7) Dec.
Some Six-Inch Meter Tests and How They Were Made.* Frank C. Kimball, (28) Dec.
The Tweeddale Water Purifying System.* (20) Jan. 14.
Plant of the Columbus Power Company, Columbus, Georgia.* (14) Jan. 16; (27) Jan. 23.
Philadelphia's New Fire Fighting Service.* (20) Jan. 21.
Water-Power Electrical Development in Northern Indiana.* (14) Jan. 23.
Relocating a Large Pumping Main Under Pressure at Philadelphia.* Seth M. Van Loan. (14) Jan. 23.
The New Sebago Lake Reservoir of the Portland Water Company.* Edmund M. Blake. (14) Jan. 23.
A Flood Test of Two Large Riveted Steel Pipe Lines.* (14) Jan. 23.
The Water Softening Plant of the Procter & Gamble Co., Ivorydale, O.* (13) Jan. 28.
The Philadelphia Fire-Protection Pumping Station. (14) Jan. 30.
A Low-Head Mill Power at Juliette, Ga.* (14) Feb. 6.
L'Alimentation Artificielle de la Neste-Aménagement du Lac de Cap-de-Long (Hautes-Pyrénées.* P. Frick. (33) Jan. 2.
Méthodes Rapides d'Analyse des Eaux Potables. J. Malette (36) Jan. 10.
Importance Hygiénique et Procédés de Captage des Eaux Souterraines Profondes.* Ed. Imbeaux and M. E. Nourtier. (36) Serial beginning Jan. 10.

Waterways.

The Levee Theory on the Mississippi River. An Informal Discussion. (54) Vol. 51.
Foreshore Protection and Travel of Beaches. William Tregarthen Douglass, M. Inst. C. E. (63) Sup., Vol. 154.

---

* Illustrated.

Waterways—(Continued).

Dredging, with Special Reference to Rotary Cutters. James Henry Apjohn, M. Inst. C. E. (63) Sup., Vol. 154.
The Modern Equipment of Docks, with Special Reference to Hydraulic and Electric Appliances. Walter Pitt, M. Inst. C. E. (63) Sup. Vol. 154.
Dredging in New South Wales. Cecil West Darley, M. Inst. C. E. (63) Sup., Vol. 154.
Methods of Measuring the Flow of Streams. John C. Hoyt. (13) Jan. 14.
Lord Kelvin's Automatic Tide Predictor.* (19) Jan. 23.
A Concrete-Steel Lighthouse. (14) Jan. 23.
Automatic Tide Gates for the Bolsa Chica Gun Club, California.* Jas. D. Schuyler, M. Am. Soc. C. E. (13) Feb. 4.
The Cache River Drainage Survey. A. H. Bell. (13) Feb. 4.
Floods and Flood Protection Works at East St. Louis, Ill.* James F. Parr. (Abstract of Paper read before the Ill. Soc. of Engrs. and Surveyors. (13) Feb. 4.
Étude Hydrologique du Rhin Allemand et du Main, les Crues et Leur Prévision. Ed. Maillet. (43) 2e Trimestre, 1908.
Hydraulique Fluviale; Verification Théorique des Lois Empiriques Relatives à la Forme du Lit des Rivières Navigables a Fond Mobile. M. Fargue. (43) 2e Trimestre, 1908.

* Illustrated.

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

March, 1904.

PROCEEDINGS - VOL. XXX—No. 3

Published at the House of the Society, 220 West Fifty-seventh Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXX. No. 3.

MARCH, 1904.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1904.

American Society of Civil Engineers.

OFFICERS FOR 1904.

President, CHARLES HERMANY.

Vice-Presidents.

Term expires January, 1905:
L. F. G. BOUSCAREN,
JAMES D. SCHUYLER.

Term expires January, 1906:
F. S. CURTIS,
S. L. F. DEYO.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1905:
RICHARD S. BUCK,
GEORGE H. PEGRAM,
WILLIAM J. WILGUS,
WILLIAM JACKSON,
EDMUND F. VAN HOESEN,
JAMES L. FRAZIER.

Term expires January, 1906:
ALFRED CRAVEN,
JOSEPH O. OSGOOD,
GEORGE S. DAVISON
E. C. LEWIS,
HUNTER McDONALD.
ELWOOD MEAD.

Term expires January, 1907:
CHARLES S. GOWEN,
NELSON P. LEWIS,
JOHN W. ELLIS,
GEORGE S. WEBSTER
RALPH MODJESKI,
CHARLES D. MARX.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:
S. L. F. DEYO,
L. F. G. BOUSCAREN,
RICHARD S. BUCK,
WILLIAM J. WILGUS.
CHARLES S. GOWEN,

On Publications:
GEORGE H. PEGRAM,
ALFRED CRAVEN,
JOSEPH O. OSGOOD,
GEORGE S. DAVISON.
HUNTER McDONALD.

On Library:
NELSON P. LEWIS,
WILLIAM JACKSON,
E. C. LEWIS,
RALPH MODJESKI,
CHARLES WARREN HUNT

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—L. F. G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - 588 Columbus
CABLE ADDRESS, - - - - - "Ceas, New York."

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

March 2d, 1904.—The meeting was called to order at 8.40 P. M.; Vice-President S. L. F. Deyo in the chair; Charles Warren Hunt, Secretary; and present, also, 193 members* and 14 guests.

The minutes of the Annual Meeting, and of the meetings of February 3d and 17th, 1904, were approved as printed in *Proceedings* for February, 1904.

The Chair declared the ballot on the proposed Union Engineering Building closed, and appointed Messrs. John G. Van Horne, John C.

* Registered, but at least 100 failed to register.

Temple, Albert Carr, S. T. Wagner and H. A. La Chicotte as tellers to canvass the ballot.

The Secretary reported that a sufficient number of ballots on the appointment of a Special Committee on "Concrete and Steel-Concrete" had been received to enable a count to be made.

It was moved, seconded and carried, that the matter be referred to the Board of Direction.

A paper by Herbert J. Wild, Jun. Am. Soc. C. E., entitled "Substructure of the Marsh River Bridge," was presented by the author and illustrated with lantern slides. The subject was discussed by G. B. Francis, M. Am. Soc. C. E.

The Secretary presented a letter from Charles G. Darrach, M. Am. Soc. C. E., forwarding some samples of concrete made during freezing weather. The subject was discussed by Messrs. G. B. Francis, R. W. Leslie, J. J. R. Croes, Charles S. Gowen, W. A. Aiken and others.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Charles White Curry, Zacualpan, Vera Cruz, Mexico.
Edwin Lincoln Grimes, Troy, N. Y.
William Bancroft Potter, Schenectady, N. Y.
Richard Quinn, Fort St. Philip, La.
Baird Snyder, Jr., Lansford, Pa.
George Elliott Verrill, New Haven, Conn.
James Gilbert White, New York City.
James Edward Whitfield, Philadelphia, Pa.

As Associate Members.

Charles Edwin Collins, Philadelphia, Pa.
James Dougan, New York City.
John Stanton Ely, Philadelphia, Pa,
Nathan Clifford Grover, Orono, Maine.
Abraham Tracy Hardin, New York City.
Harry Hodgman, Amherstburg, Ont., Canada.
William August Hunicke, St. Louis, Mo.
Joseph Patton McLean, Jersey City, N. J.
Theodore Clifford Phillips, New York City.
Joseph Springer Swindells, Mt. Kisco, N. Y.
Joseph Lee Wickes, Baltimore, Md.

The Secretary announced the transfer of the following candidates, by the Board of Direction, on March 1st, 1904, from the grade of Associate Member to the grade of Member:

As Members.

Cyrus Cates Babb, Washington, D. C.
Cary Talcott Hutchinson, New York City.
Isaac Mathewson, Alarcon, Guerrero, Mexico.
Jay Johnson Morrow, Washington, D. C.
Emmet Abner Steece, Burlington, Iowa.
Samuel Storrow, Los Angeles, Cal.
Taro Tsuji, Tokyo, Japan.

The Secretary announced the election of the following candidates by the Board of Direction on March 1st, 1904:

As Juniors.

Edward Warren Banker, Philadelphia, Pa.
Milo Hamilton Brinkley, Salt Lake City, Utah.
John Otis Burrage, San Francisco, Cal.
Henry Schwing Kleinschmidt, Salt Lake City, Utah.
Thomas Burton McIntire, New York City.
Albert Jefferson Mayell, New York City.
Cornelius Joseph O'Connor, New York City.
Arthur Johnson Sackett, Jacksonville, Fla.

The Secretary presented the report of the tellers appointed to canvass the ballot on the proposed Union Engineering Building, as follows:

"New York, March 2d, 1904.

"The tellers appointed for the purpose report that they have canvassed the ballot on Union Engineering Building, with the following result:

"Total number of ballots found correct and counted.......		1 801
In favor of the Union..........................	662	
Against the Union............................	1 139	
	——	1 801

"Respectfully submitted,
"John G. Van Horne,
"John C. Temple,
"Albert Carr,
"Samuel Tobias Wagner,
"H. A. La Chicotte."

Adjourned.

March 16th, 1904.—The meeting was called to order at 8.30 P. M., Foster Crowell, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 107 members and 27 guests.

A paper, by W. D. Taylor, M. Am. Soc. C. E., entitled "The Location of the Knoxville, La Follette and Jellico Railroad, of the Louisville and Nashville System," was presented by the Secretary, who also presented communications on the subject from Messrs. Emile Low, E. J. Beard, William G. Raymond, Walter Watson and William P. Watson.

The paper was discussed further by Messrs. J. G. Tait, F. Lavis and W. H. Coverdale.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 1st, 1904.—8.30 P. M.—Vice-President Curtis in the Chair; Charles Warren Hunt, Secretary, and present, also, Messrs. Craven, Ellis, Gowen, N. P. Lewis, and Webster.

The Secretary reported that a sufficient number of votes had been received on the proposition for the appointment of a Special Committee on "Concrete and Steel-Concrete," so that they may be canvassed, under the Constitution, and was instructed to report this fact to the meeting of the Society on the 2d inst.

The seven geographical districts into which the Society has heretofore been divided for the purpose of the Nominating Committee, were adopted for the next year.

Applications were considered and other routine business transacted.

Seven Associate Members were transferred to the grade of Member, and eight candidates for Junior were elected.*

Adjourned.

---

* See pages 130 and 131.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, April 6th, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "A Phenomenal Land Slide," by D. D. Clarke, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, April 20th, 1904.—8.30 P. M.—At this meeting, a paper, entitled "Lateral Earth Pressure and Related Phenomena," by E. P. Goodrich, Jun. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, May 4th, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Lake Cheesman Dam and Reservoir," by Charles L. Harrison, M. Am. Soc. C. E., and Silas H. Woodard, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an engineering exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

Robert Moore, M. Am. Soc. C. E,, St. Louis, Mo., *Chairman.*
Edward C. Carter, M. Am. Soc. C. E., Chicago, Ill.
Mordecai T. Endicott, M. Am. Soc. C. E., Washington, D. C.
James L. Frazier, " " Frankfort, Ind.
William Jackson, " " Boston, Mass.
Emil Kuichling, " " New York, N. Y.
J. L. Van Ornum, " " St. Louis, Mo.
John F. Wallace, " " Chicago, Ill.
H. J. Pfeifer, Assoc. M. Am. Soc. C. E., St. Louis, Mo., *Secretary.*

INTERNATIONAL ENGINEERING CONGRESS.

The list of subjects for discussion at the Congress, published in the *Proceedings* for February, 1904, has been amended as follows:

Change title of subject No. 32 to read,

32. Mining:
  - *a.* Surveying;
  - *b.* Hoisting;
  - *c.* Ventilation.

Add the following subjects:

34. Gas Engines.
35. Surveying.
36. Ocean Hydrography.
37. Wharves and Piers.

Papers, from the standpoint of American Practice, have already been assured on the various subjects, as follows:

Harbors, Natural Waterways, Artificial Waterways and Fortifications:

By Officers of the Corps of Engineers, U. S. A.

Lighthouses and Other Aids to Navigation:

By Officers of the Lighthouse Board, U. S. A.

Ordnance:

By Officers of the Ordnance Department, U. S. A.

SURVEYING:

By Officers of the U. S. Coast and Geodetic Survey, and H. M. Wilson, Geographer, U. S. Geological Survey.

NAVAL ARCHITECTURE:

By Rear Admiral W. L. CAPPS, Chief Constructor, U. S. N.

MARINE ENGINEERING:

By Professor W. F. Durand, Ithaca, N. Y.

DRY DOCKS:

By Rear Admiral M. T. ENDICOTT, Chief of Bureau of Yards and Docks, U. S. N.

TRAFFIC ON IMPROVED WATERWAYS, etc.:

By EDWARD P. NORTH, New York City.

PURIFICATION OF WATER FOR DOMESTIC USE:

By ALLEN HAZEN, New York City.

PURIFICATION OF WATER FOR THE PRODUCTION OF STEAM:

By J. O. HANDY, Pittsburg, Pa.

TURBINES AND WATER WHEELS:

By Professor GARDNER S. WILLIAMS, Ithaca, N. Y.

IRRIGATION:

By ELWOOD MEAD, Chf. Irrigation Investigations, Washington, D. C.

RAILROAD TERMINALS:

By ELMER L. CORTHELL, New York City.

UNDERGROUND RAILWAYS:

By WILLIAM BARCLAY PARSONS, New York City.

LOCOMOTIVES AND OTHER ROLLING STOCK:

By GEORGE GIBBS, New York City.

LIVE LOADS FOR RAILROAD BRIDGES:

By HENRY W. HODGE, New York City.

THE SUBSTITUTION OF ELECTRICITY FOR STEAM AS A MOTIVE POWER:

By JAMES G. WHITE, New York City.

SEWAGE DISPOSAL:

By GEORGE W. FULLER, New York City.

DISPOSAL OF MUNICIPAL REFUSE:

By RUDOLPH HERING, New York City.

VENTILATION OF TUNNELS:

By CHARLES S. CHURCHILL, Chief Engineer, Norfolk and Western R. R., Roanoke, Va.

HIGHWAYS:

By JAMES OWEN, Newark, N. J., and WILLIAM E. MCCLINTOCK, Boston, Mass.

CONCRETE AND CONCRETE-STEEL:

By EDWIN THACHER, New York City.

DEEP FOUNDATIONS:

By JOHN F. O'ROURKE, New York City.

THE MANUFACTURE OF STEEL:

By WILLIAM METCALF, Pittsburg, Pa.

TESTS OF MATERIALS OF CONSTRUCTION:

By WILLIAM R. WEBSTER, Philadelphia, Pa.

PASSENGER ELEVATORS:

By THOMAS E. BROWN, New York City.

PUMPING MACHINERY:

By IRVING H. REYNOLDS, Youngstown, Ohio.

CENTRIFUGAL PUMPS:

By William Mayo Venable, New Orleans, La.

DREDGES: THEIR CONSTRUCTION AND PERFORMANCE:

By A. W. ROBINSON, Montreal, Canada, and F. B. MALTBY, Memphis, Tenn.

ELECTRICAL POWER—GENERATING STATIONS AND TRANSMISSION:

By L. B. STILLWELL, New York City.

ENGINEERING EDUCATION:

By Professor ROBERT FLETCHER, Hanover, N. H., and Professor CALVIN M. WOODWARD, St. Louis, Mo.

WHARVES AND PIERS:

By JOHN A. BENSEL, New York City.

Advices recently received indicate much interest in the Congress in Europe, and many papers from England, France, Holland and other foreign countries seem to be assured.

THE *TECHNOLEXICON* OF THE SOCIETY OF GERMAN ENGINEERS.

At the request of Dr. Hubert Jansen, Editor-in-Chief of the *Technolexicon* of the Verein Deutscher Ingenieure, the following announcement is made:

"The universal technical dictionary for translation purposes, in English, German and French, the compilation of which was begun in 1901 under the auspices of the Society of German Engineers, has received help, up to the present time, from 363 technical societies at home and abroad: 51 of these are English, American, South African, etc., 274 German, Austrian, and German-Swiss, and 38 French, Belgian, and French-Swiss societies. Of firms and individual collaborators, 2 573 have promised contributions.

"The excerption of texts in one, two or three languages (handbooks, pamphlets, business-letters, catalogues, price-lists, etc.), and of

the existing dictionaries has yielded 1 920 000 word-cards so far. To these will be added within the next two years (by the middle of 1906) the hundred thousands of word-cards that will form the result of the original contributions—those already sent in and those still expected —of the 2 573 collaborators at home and abroad, when the editors in Berlin have finished them for the press. Specially made handy note-books had been placed at the disposal of the collaborators to write their collections in, of which 317 have come in filled so far.

"All the outstanding contributions will be called in **by Easter of this year, 1904.** The collaborators are therefore requested to close their note-books or other contributions—unless a later term has been especially arranged with the Editor-in-Chief—by the end of March and to forward them to the address given below. As the printing of the *Technolexicon* is to begin in the middle of 1906, delayed contributions can be made use of in exceptional cases only up to that time.

"The Editor-in-Chief will be pleased to give any further information wanted. Address: Technolexicon, Dr. Hubert Jansen, Berlin (N. W. 7), Dorotheenstrasse 49."

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ACCESSIONS TO THE LIBRARY.

From February 10th to March 8th, 1904.

DONATIONS.*

CAMBRIA STEEL.

A Handbook of Information Relating to Structural Steel Manufactured by the Cambria Steel Co., Containing Useful Tables, Rules, Data and Formulæ for the Use of Engineers, Architects, Builders and Mechanics. Leather, 7 x 4 ins., 10 + 464 pp., illus. Philadelphia, Cambria Steel Co., 1903. $1.00.

This sixth edition of the handbook contains all the data of the fourth and fifth editions, which have been corrected and revised where necessary. It also contains a considerable amount of new matter relating to new sections of angles and T-bars, and additional sizes of billets, blooms, ingots, and edged and sheared plates. The weights of angles, Z-bars and T-bars now given are those adopted as standards by the Association of American Steel Manufacturers. Other new matter, which has been introduced, consists of tables of safe loads and dimensions for plate and angle columns and for Z-bar columns with side plates. Tables have been added showing the section moduli and moments of inertia for all the built-up columns for which the safe loads are tabulated, which values will be of assistance in cases where it is necessary to consider the effect of eccentric loads in figuring the strength of the columns. Tables of safe loads for angles, T-bars and Z-bars acting as beams with uniformly distributed loads have also been inserted.

LES POMPES.

Par R. Masse. Préface de M. Hatton de la Goupillière. Cloth, 11 x 8 ins., 16 + 528 pp., illus. Paris, Vve. Ch. Dunod, 1903. 32 francs.

This work is made up largely of articles written by the author for the *Revue de Mécanique*, and his descriptions of the various types of pumps exhibited at the Paris Exposition of 1900. The general principles governing the subject are set forth in the first chapter which comprises a brief epitome of the theory of hydraulics, the function and work of pumps, motive power, steam engines, electric motors and the older and simpler forms of hand pumps. The theory and construction of the various types of pumps in general use are next treated, the text being illustrated by a large number of figures including numerous sections showing details of construction. Both direct and indirect acting pumps are treated, and numerous examples of each class are shown. The important subjects of rotary and centrifugal pumps are treated in Chapter III, while Chapter IV treats of pulsometers and injectors. Fire-engines and fire-boats are treated also in the last chapter.

ALTERNATING CURRENTS:

Their Generation, Distribution, and Utilization. By George T. Hanchett, M. Am. Inst. E. E. Cloth, 7½ x 5 ins., 175 pp., illus. New York, John Wiley & Sons, 1904. $1.00 net.

The preface states that there are to-day many practical engineers of experience in charge of lighting and power plants and construction work who have a thorough knowledge of direct-current work in all its various branches, yet a comparatively vague idea of the phenomena of alternating currents and the apparatus for their generation and utilization. This is especially true in connection with polyphase systems, which are becoming more and more generally used, and which possess, in many cases, advantages over the direct-current and single-phase alternating-current systems. The endeavor of this book is to explain as clearly and simply as possible, the phenomena as well as the apparatus of alternating currents of electricity in their various practical phases. The Contents are: Hydraulic Analogies of Inductance and Capacity Combinations; Alternating Current Principles; Single Phase Constant Potential Transformers; Phase Difference and Vector Summation; Copper Calculations for Polyphase Circuits; Alternating Current Measurements; The Induction Motor; The Rotary Converter; Alternating Current Generators and Synchronous Motors; The Management of Alternating Current Machinery; Management of Induction Motors.

---

*Unless otherwise specified, books in this list have been donated by the publishers.

LES MOTEURS A ESSENCE POUR AUTOMOBILES.

Leçons Professées en 1903–1904 à la Faculté des Sciences de l'Université de Bordeaux. Par L. Marchis. Paper, 10 x 6½ ins., 15 + 470 pp., illus. Paris, Vve. Ch. Dunod, 1904. Broché, 15 francs; cartonné, 16 francs, 50.

The desire to interest readers who are skilled in the mechanical arts and who understand the principles on which rest the construction and the functions of automobile motors has led the author to limit his subject to the study of the *moteurs à essence* alone. He has discussed the question with its developments, and has furnished information for industrial practice. The Contents are: Le Dévelopment de l'Industrie Automobile; Les Types de Moteurs à Explosion Employés en Automobilisme; Le Refroidissement des Moteurs; Distribution; Échappement; Régulation; Réservoirs; Les Carburateurs; Allumage par des Procédés non Électriques; Allumage Électrique par Étincelle d'Induction; Allumage par Magnétos et par Dynamos; Équilibrage des Moteurs en Général et plus Particulièrèment des Moteurs à Explosion. There is an index of six pages.

Gifts have also been received from the following:

Am. Electrochemical Soc. 1 pam.
Am. Inst. Min. Engrs. 1 bound vol.
Am. Iron and Steel Assoc. 1 pam.
Am. Ry. Assoc. 1 pam.
Assoc. Amicale des Anciens Élèves de l'École Centrale. 1 vol.
Bituminous Coal Trade Assoc. 1 pam.
Blanchard, Arthur H. 1 bound vol.
Boston, Mass.—Statistics Dept. 1 vol.
Brough, B. H. 1 pam.
Buffalo, N. Y.—Dept. of Pub. Works. 1 vol.
Canada—Geol. Surv. Dept. 1 vol.
City Record. 2 bound vol.
Clifton Power Co. 8 pam.
Coll. of the City of N. Y. 1 pam.
Colo.—Agri. Exper. Station. 4 pam.
Columbia Univ. 1 vol., 2 pam.
Delaware, Lackawanna & Western R. R. Co. 1 pam.
Deutsch-Amerikanischer Techniker-Verband. 1 pam.
Fall River, Mass.—Watuppa Water Board. 1 pam.
Fisk, W. L. 1 vol.
France—Ministre des Travaux Publics. 1 pam.
Great Britain—Patent Office. 12 pam.
Ill.—Agri. Exper. Station. 5 pam.
Inst. of Civ. Engrs. of Ireland. 1 vol.
Iron & Steel Inst. 1 bound vol.
Judson, Wm. P. 1 pam.
Kenyon, G. C. 2 pam.
Königliche Technische Hochschule zu Berlin. 1 pam.
League of Am. Municipalities. 1 pam.
McGill Univ. 1 bound vol.
Mich.—State Board of Health. 1 pam.
Middletown, Conn.—Water Commrs. 1 pam.
Midland Ry. Co. 1 pam.
Miller, Hiram A. 1 pam.
Minneapolis & St. Louis R. R. Co, 1 pam.
N. J.—Board of Health. 1 pam.
N. Y. City—Board of Health. 1 pam.
N. Y. City—Commr. of Pub. Works. 1 pam.
N. Y. City—Municipal Explosives Comm. 1 vol.
Ontario—Registrar-Gen. 1 pam.
Poor's Ry. Manual Co. 1 pam.
Quinette de Rochemont, E. T. 1 pam.
St. Paul, Minn.—Board of Water Commrs. 1 pam.
Sims, A. V. 1 pam.
Southern Pacific Co. 1 pam.
Univ. of Mich. Lib. 1 pam.
Univ. of Pa. 1 pam.
U. S. Light-House Board. 2 pam.
Victoria—Legislative Assembly. 1 pam.
Western Ry. Club. 1 vol.
Woodbury, C. J. H. 1 bound vol.

BY PURCHASE.

Testing of Electro-Magnetic Machinery and other Apparatus. By Bernard Victor Swenson and Budd Frankenfield. Vol. I. Direct Currents. New York, The Macmillan Company, 1904.

Wireless Telegraphy and Telephony: A Comprehensive Exposition of the Progress made by Wireless Telegraphy from Early Beginnings; Followed by a Popular Description of the Method and the Instruments Used in the Orling-Armstrong System of Wireless Telegraphy and Telephony through the Ground. Compiled by Maurice Ernst. London, *Electricity* Office.

Engine Tests and Boiler Efficiencies. By J. Buchetti. Translated and Edited from the Third Edition by Alexander Russell, M. I. E. E. Westminster, Archibald Constable & Co., Ltd., 1903.

Die Entwickelung des Niederrheinisch-Westfälischen Steinkohlen-Bergbaues in der zweiten Hälfte des 19. Jahrhunderts. Herausgegeben vom Verein für die bergbaulichen Interessen im Oberbergamtsbezirk Dortmund in gemeinschaft mit der Westfälischen Berggewerkschaftskasse und dem Rheinisch-Westfälischen Kohlensyndikat. Vol. 1. Berlin, Julius Springer, 1903.

Die Wagner-Fennel'schen Tachymeter. Der Fabrik geodätischer Instrumente von Otto Fennel Söhne in Cassel. Dritte verbesserte Auflage. Von Adolf Fennel. Stuttgart, Konrad Wittwer, 1904.

Maps: Their Uses and Construction. A Short Popular Treatise on the Advantages and Defects of Maps on Various Projections, Followed by an Outline of the Principles Involved in their Construction. By G. James Morrison. Second Edition, Revised and Enlarged. London, Edward Stanford, 1902.

The Encyclopedia Americana. A General Dictionary of the Arts and Sciences, Literature, History, Biography, Geography, etc., of the World. New York, Chicago, The American Company.

The World Almanac and Encyclopædia, 1904. New York, The Press Publishing Co., New York World, 1904.

The Removal and Disposal of Town Refuse. By William H. Maxwell. London, The Scientific Publishing Company, Ltd., 1898.

Résistance des Matériaux Appliquée aux Constructions: Methodes Practiques par le Calcul et la Statique Graphique. Vol. 1. Paris, Vve. Ch. Dunod, 1904.

The Official Report of the International Fire Prevention Congress Convened by the Executive of the British Fire Prevention Committee, Held in London, July 6th to 9th, 1903. London, British Fire Prevention Committee, 1903.

Annuaire Statistique et Descriptif des Distributions d'Eau de France, Algérie, Tunisie, Belgique, Suisse et Grand-Duché de Luxembourg. Par Imbeaux, Hoc, Van Lint et Peter. Paris, Vve. Ch. Dunod, 1903.

SUMMARY OF ACCESSIONS.

February 10th to March 8th, 1904.

Donations (including 5 duplicates)	80
By purchase	19
Total	99

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
BARB, CYRUS CATES. Engr., U. S. Geological Survey, Washington, D. C	Jun. Assoc. M. M.	Feb. 2, 1892 Feb. 3, 1897 Mar. 1, 1904
CUNNINGHAM, JOSEPH HOOKER. 661 Worcester Blk., Portland, Ore	Assoc. M. M.	Sept. 6, 1899 Feb. 2, 1904
GRIMES, EDWIN LINCOLN. Chf. Engr., Bureau of Water Supply, 47 State St., Troy, N. Y		Mar. 2, 1904
HANDBURY, THOMAS HENRY. Lt.-Col., Corps of Engrs., U. S. A., Room 92, Flood Bldg., San Francisco, Cal		Feb. 3, 1904
HUTCHINSON, CARY TALCOTT. Cons. Elec. Engr., 56 Pine St., New York City	Assoc. M. M.	Mar. 4, 1896 Mar. 1, 1904
MORROW, JAY JOHNSON. Capt., Corps of Engrs., U. S. A., Asst. to Engr. Commr. of the District of Columbia, District Bldg., Washington, D. C	Assoc. M. M.	June 5, 1901 Mar. 1, 1904
SANDERS, WILLIAM HORATIO. 915 Grand View Ave., Los Angeles, Cal		Feb. 3, 1904
SCARBOROUGH, FRANCIS WINTHROP. Engr., M. of W., C. & O. Ry., Richmond, Va	Jun. Assoc. M. M.	Sept. 3, 1890 Mar. 6, 1895 Feb. 2, 1904
SNYDER, BAIRD, Jr. Asst. Supt., Lehigh Coal & Nav. Co., Lansford, Pa		Mar. 2, 1904
STEECE, EMMET ABNER. City Engr., City Hall, Burlington, Iowa	Assoc. M. M.	Dec. 4, 1901 Mar. 1, 1904
VERRILL, GEORGE ELLIOT. 603 Elm St., New Haven, Conn		Mar. 2, 1904
WHITE, JAMES GILBERT. 43 Exchange Pl., New York City		Mar. 2, 1904
WHITFIELD, JAMES EDWARD. 406 Locust St., Philadelphia, Pa.		Mar. 2, 1904

ASSOCIATE MEMBERS.

COLLINS, CHARLES EDWIN. Cons., Civ. and Hydr. Engr., Care, Woodlawn Inn, Pittsfield, Mass		Mar. 2, 1904
CRAIG, PHILIP INSLEY. Chf. Engr., Phil. & Easton Ry. Co., Easton, Pa		Feb. 3, 1904
DOUGAN, JAMES. Asst. Engr. with Clinton & Russell, 32 Liberty St., New York City	Jun. Assoc. M.	Mar. 5, 1901 Mar. 2, 1904
GROVER, NATHAN CLIFFORD. Engr., U. S. Geological Survey, Orono, Me		Mar. 2, 1904
HARDIN, ABRAHAM TRACY. Engr., M. of W., N. Y. C. & H. R. R. R., Grand Central Station, New York City		Mar. 2, 1904
HODGMAN, HARRY. Amherstburg, Ont., Canada		Mar. 2, 1904
HUNICKE, WILLIAM AUGUST. 2937 Henrietta St., St. Louis, Mo.		Mar. 2, 1904

		Date of Membership
MacCracken, George Gere. University Heights, New York City	Jun. Assoc. M.	Feb. 5, 190 Feb. 3, 190
McLean, Joseph Patton. 31 Highland Ave., Jersey City, N. J.		Mar. 2, 190
Noble, Clarence Warren. 405 Brooklyn Ave., Kansas City, Mo.		Feb. 3, 190
Paterson, Harry Thomas. Asst. Engr., U. S. Geological Survey, Roswell, N. Mex.		Feb. 3, 190
Phillips, Theodore Clifford. Civ. and Hydr. Engr., 635 Park Row Bldg., New York City		Mar. 2, 190
Pierce, James Wilson. City Engr., City Hall, Cambridge, Mass.		Feb. 3, 190
Prouty, Edward Nathan. Asst. Prof. of R. R. Eng., Univ. of California, 2237 Vine St., Berkeley, Cal.		Feb. 3, 190
Schaeffer, Amos. Asst. Engr., Rapid Transit R. R. Comm., 500 West 149th St., New York City		Feb. 3, 190
Scott, Charles Bruce. Elkins, W. Va.		Feb. 3, 190
Swindells, Joseph Springer. San., Hydr. and Constr. Engr., 4 West 14th St., Room 3, New York City	Jun. Assoc. M.	Feb. 2, 189 Mar. 2, 190
Wickes, Joseph Lee. Commr. of Street Cleaning, City Hall, Baltimore, Md.		Mar. 2, 190
Young, Eddy Elbert. 426 West 23d St., New York City		Jan. 6, 190

JUNIORS.

	Date of Membership
Davies, William Gomer. Care, U. S. Geological Survey, Yuma, Ariz.	Feb. 2, 190
Mayell, Albert Jefferson. 550 East 164th St., New York City	Mar. 1, 190
O'Connor, Cornelius Joseph. 1018 Prospect Ave., Bronx, New York City	Mar. 1, 190
Richmond, Julian Pierre William. 1144 Tinton Ave., New York City	Feb. 2, 190
Witherell, Frederick Whitefield. Room 1200, Bank for Savings Bldg., Pittsburg, Pa.	Oct. 6, 190
Yen, Tuck Ching Strong. Asst. Div. Engr., Canton-Hankow Ry., Canton, China	Dec. 1, 190

CHANGES OF ADDRESS.

MEMBERS.

Adgate, George........Western Mgr., Foundation & Contr. Co., 509 McCague Bldg., Omaha, Nebr.

Brown, William Maxwell........Engr., Sewerage Works, Met. Water and Sewerage Board, 1 Ashburton Pl., Boston, Mass.

CAMPBELL, JOHN LOGAN............Chf. Engr., Gasconade Ry. Constr. Co., Prin. Asst. Engr., St. L., K. C. & C. Ry., 512 Frisco Bldg., St. Louis, Mo.
CRUMP, RALPH LEE................Englewood, N. J.
DAVIS, CHARLES E. L. B............Lt.-Col., Corps of Engrs., U. S. A., U. S. Engr. Office, Jones Bldg., Detroit, Mich.
GIFFORD, GEORGE EDWIN............Eastern Representative, The King Bridge Co., 277 Broadway, New York City.
GRESHAM, ROBERT HALL............302 Bowie St., San Antonio, Tex.
HALL, BENJAMIN MORTIMER.........Civ. and Min. Engr.; Cons. Engr., Reclamation Service, U. S. Geological Survey (Hall Bros.), 409 Temple Court, Atlanta, Ga.
HARLOW, JAMES HAYWARD..........Chf. Engr., Susquehanna Elec. Power Co., 3 East Lexington St., Baltimore, Md.
HAYDEN, WILLIAM WALLACE........40 Spruce St., Memphis, Tenn.
INGALLS, OWEN LOVEJOY ....Engr. in Chg. of Manila Sewerage System, Manila, Philippine Islands.
IRWIN, JAMES CLARK...............518 Grand Central Station, New York City.
KELLER, CHARLES................ Capt., Corps of Engrs., U. S. A., Engr. Officer, Dept. of Mindanao, and Engr., Moro Province, Zamboanga, Mindanao, Philippine Islands.
KUNZ, FREDERIC CHARLES....... ...Cons. Engr., Bridge and Constr. Dept., Pennsylvania Steel Co., Steelton, Pa.
LINVILLE, JACOB HAYS ....Cons. Engr., 95 East Baltimore Ave., Lansdowne, Pa.
MELCHER, FRANK OTIS.............Gen. Supt., Choc., Okla. & Gulf R. R., Little Rock, Ark.
SERJEANT, HUGH...................Asst. Engr., Riversdale, Riversdale Rd., Burswood, Western Australia.
SPRING, FRANCIS JOSEPH EDWARD....Chairman, Harbor Board, Madras, India.
STUART, FRANCIS LEE ....Dist. Engr., B. & O. R. R., Room 4, Walsh Bldg., Cumberland, Md.
TAYLOR, HARRY.....................Capt., Corps of Engrs., U. S. A., Engr. Officer, Dept. of Luzon, Manila, Philippine Islands.
THOMPSON, BENJAMIN ....41 First National Bank, Chattanooga, Tenn.
TUBBS, JOSEPH NELSON.............Gen. Insp., State Dept. of Public Works, 57 Rutgers St., Rochester, N. Y.
TUCKER, LESTER WALDO ....187 Columbia Heights, Brooklyn, N. Y.
VANDEVANTER, CHARLES OSCAR......(Vandevanter & Hood), 238 Park Ave., Baltimore, Md.

ASSOCIATE MEMBERS.

ATKINS, HAROLD BEDFORD..........Cons. Engr., Fifth Ave., East, Roselle, N. J.

BRYNN, PER.......................Care, Am. Bridge Co., Ambridge, Pa.

BURNS, CLINTON SUMNER............Civ., Hydr. and San. Engr. (Burns & McDonnell), 509 Dwight Bldg., Kansas City, Mo.

BURNS, JUSTIN......................First Asst. Engr, Canton-Hankow Ry., Canton, China.

DOERFLING, RICHARD GEORGE.......Room 91, Flood Bldg., San Francisco, Cal.

EAVENSON, HOWARD NICHOLAS......Chf. Engr., United States Coal & Coke Co., Gary, McDowell Co., W. Va.

EDWARDS, WARRICK RIGELEY........Asst. to Engr., Bridges and Bldgs., B. & O. R. R., Mt. Royal Station, Baltimore, Md.

FISH, JOHN CHARLES LOUNSBURY....Assoc. Prof., Civ. Eng., L. S. Jr. Univ.; Pres., Board of Health of Palo Alto, 382 Lincoln Ave., Palo Alto, Cal.

GIDEON, ABRAHAM.................Asst. Engr., Cons. Engr.'s Office, Manila, Philippine Islands.

HILL, THEODORE WILLIAM..........613 The Nasby, Toledo, Ohio.

HOMAN, WILLIAM MACLEAN.........Bethlehem, Orange River Colony, South Africa.

HOWE, GEORGE EDWARD............Care, City Engr.'s Office, Columbus, Ohio.

LLEWELLYN, FREDERICK THOMAS.....Care, Am. Bridge Co. of N. Y., 100 Broadway, New York City.

PARKER, CHARLES FREDERIC........(Supt. of Socavon Mines), Cia. Minera de Penoles, La Ojuela, Mapimi, Durango, Mexico.

SMITH, PEMBERTON.................Representative, U. S. Steel Products Export Co., Buenos Aires, Argentine Republic.

THOMPSON, ARTHUR WEBSTER.......Supt., Wheeling Div., B. & O. Ry., Wheeling, W. Va.

TURNER, GEORGE DALLAS BAIRD....Gen. Mgr., J. I. C. Min. & Milling Co., Box 377, Salt Lake City, Utah.

WAITE, GUY BENNETT..............Pres. and Treas., Guy B. Waite Co., 1919 Seventh Ave., New York City.

WALDRON, SAMUEL PAYSON..........Care, Am. Bridge Co., 7 West 22d St., New York City.

WARRINGTON, HARRY ESMOND.......Asst. Engr., C., N. O. & T. P. Ry. Co., 66 Ingalls Bldg., Cincinnati, Ohio.

JUNIORS.

BURWELL, ROBERT LEMMON.........187 Columbia Heights, Brooklyn, N. Y,

DAVIS, GEORGE JACOB, Jr...........Hydr. and San. Engr., 20 Grant Bldg., Atlanta, Ga.

FOSS, JOHN HARRISON..............Asst. Engr., Hamakua Ditch, Huelo, Maui, Hawaii.

HARSHBARGER, ELMER DWIGHT......520 Spring St., St. Louis, Mo.

HOWES, RALPH HOLT................619 S. Warren St., Syracuse, N, Y.

RUNYON, WILLIAM KEEPER..........Locating Engr., Canton-Hankow Ry. (Imperial Chinese Ry. Administration), Shanghai, China.

SAWYER, WILBUR CYRUS............Asst. Engr., U. S. Geological Survey, Washington, D. C.

SPENCER, LOUIS BERNARD...........Cons. Engr., Box 377, Salt Lake City, Utah.

VEUVE, ERLE LEROY................Asst. Engr., Pacific Elec. Ry. Co., 711 Kensington Rd., Los Angeles, Cal.

FELLOWS.

DARWIN, HARRY GILBERT...........Engr. in Chg. of San. Inspection, Hackensack Water Co., New Milford; Address, 84 Clinton Pl., Hackensack, N. J.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(February 9th to March 7th, 1904.)

NOTE.—*This list is published for the purpose of placing before the member of the Society the titles of current engineering articles, which can be referre to in any available engineering library, or can be procured by addressin the publication directly, the address and price being given whereve possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number pre fixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal, London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.

LIST OF ARTICLES.

Bridge.

A Solid Floor for Deck Girders.* (15) Feb. 12.
Fourth Street Bridge, Waterloo, Iowa.* M. L. Newton. (Address delivered before the Iowa Eng. Soc.) (14) Feb. 18.
Two Large Plate Girder Railway Bridges.* (13) Feb. 18.
Moving a Paris Footbridge over the Seine and Withdrawing Its Piers by Hydraulic Jacks.* Rene Bonnin. (13) Feb. 18.
Stone Highway Bridge over the Connecticut River at Hartford.* (15) Feb. 19.
Twin Lift Bridge Operated by Gas Engines; New Draw over Newark Bay, Central R. R. Co. of New Jersey.* (13) Feb. 25.
Scherzer Rolling Lift Bridge over Newark Bay.* (15) Feb. 26.
Double Lift Bridge: Central of New Jersey.* (40) Feb. 26.
A Simple Traveler for Erecting a Viaduct.* (14) Feb. 27.
The Herkimer Viaduct for the Utica & Mohawk Valley Railway.* Wilbur J. Watson, Assoc. M. Am. Soc. C. E. (14) Feb. 27.
Rolling Lift Bridges for the Cent. R. R. of N. J. over Newark Bay.* (18) Feb. 27; (14) Feb. 27.
A 1,000 Ton Drawbridge Moved and Lowered by Sand Jacks.* (25) Mar.
The Concrete Bridge of the Illinois Central Railroad over the Big Muddy River.* (60) Mar.
A Proposed Solution of the Brooklyn Bridge Terminal Problem.* S. S. Neff. (13) Mar. 3.
Milan Concrete-Steel Bridge at Dayton, Ohio.* (15) Mar. 4.
Masonry Construction for the Blackwell's Island Bridge.* (14) Mar. 5.
The Erection of the Monongahela River Bridge, Pittsburg.* (14) Serial beginning Mar. 5.
Le Pont à Transbordeur de Nantes.* Léon Griveaud. (35) Feb.
Pont en Béton Armé, a Soissons.* Riboud. (33) Feb. 13.

Electrical.

Alternating Current Motors for Variable Speed. W. I. Slichter, Jun. Am. Soc. M. E. (55) Vol. 24.
Electrochemical Industries.* F. B. Crocker and M. Arendt. (6) Nov.
Alternating Current Generators Giving Pure Sine Waves of Electromotive Force.* Clifford C. Paterson. (26) Jan. 29.
Magnetic Dispersion in Induction Motors. (26) Jan. 29.
The Cable Works of Messrs. Pirelli and Co., Milan.* (26) Feb. 5.
On the Circle-Diagram of the Repulsion Motor. F. Creedy. (26) Serial beginning Feb. 5.
The New Trunk Telephone Exchange.* (73) Serial beginning Feb. 5.
Eddy Currents in Dynamo Machines. Michael B. Field. (73) Feb. 5.
Three-Wire Direct-Current Railway System.* (27) Feb. 6.
On the Wave Length of Free Vibrations in Antennæ and Closed Oscillating Circuits. James E. Ives. (27) Feb. 6.
The Measurement of Distributed Leakage in Transmission Lines. Frank F. Fowle. (27) Feb. 6.
Speed-Torque Characteristics of the Single-Phase Repulsion Motor. (27) Feb. 6.
The Repulsion Type of Alternating Current Motor. (27) Feb. 6.
Crompton Potentiometer.* (27) Feb. 6.
Three-Phase Working, with Special Reference to the Dublin System. Wm. Brew. (Abstract of Paper read before the Inst. of Elec. Engrs.) (26) Serial beginning Feb. 12.
The Electric Lighting of Drury Lane Theatre Royal.* (73) Feb. 12.
Application of Graphics to Power House Location.* Sidney Diamant. (27) Feb. 13.
Modern Methods of Operating Machine Tools Electrically. (27) Feb. 13.
The Frequency Changers at Montreal.* B. A. Behrend. (27) Feb. 13.
Construction and Maintenance of Electric Current Carrying Wires. A. S. Hatch. (Paper read before the Amer. Soc. of Municipal Impvts.) (24) Feb. 15.
Voltage Regulation in Alternating-Current Systems. H. S. Meyer. (Abstract of Paper read before the Liverpool Eng. Soc.) (73) Serial beginning Feb. 19.
The Distribution of Electricity in Shipyards and Engine works. J. A. Anderson. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Feb. 19.
Electricity in Manufacturing Plants. Walter M. McFarland. (Paper read before the Soc. of Naval Archts. and Marine Engrs.) (19) Feb. 20.
New Installation at City of South Norwalk Electric Works.* A. E. Winchester. (27) Feb. 20.
Grounding of Constant Potential Systems.* S. Bingham Hood. (27) Feb. 20.
Some Notes on the Cost of Generating Electrical Energy. E. J. Fox. (Paper read before the Cleveland Inst. of Engrs.) (12) Serial beginning Feb. 26; Abstract, (22) Feb. 26.
A 20 000-Volt Power Transmission Plant.* A. J. Bloemendal. (11) Feb. 26.
The Advantages of Boosting. Frank Broadbent. (26) Feb. 26.
Gutta Gentzsch, an Insulating Substance. (26) Feb. 26.
A Composite Plant at Bloomsburg, Pa.* L. S. Levy. (27) Feb 27.
Service Power Plant of the Louisiana Purchase Exposition.* (27) Feb. 27; (14) Feb. 27.

---

* Illustrated.

Electrical—(Continued).

The Seattle Municipal Light and Power Plant.* R. E. Heine. (27) Feb. 27.
Submarine Sound Telegraphy.* (46) Feb. 27.
Commutation of Continuous-Current Generators.* G. A. Neild and P. E. Banting. (Paper read before the Rugby Eng. Soc.) (47) Feb. 27.
Electrical Energy Direct from Fuel. (47) Feb. 27.
A Résumé of Our Knowledge of the Physical Properties of Current-Bearing Matter. Paul R. Heyl. (3) Mar.
Works of the Smith Premier Typewriter Company, Syracuse.* (14) Serial beginning Mar. 5.
A Controller for Regulating and Reversing Motors.* (14) Mar. 5.
Vertical Motor-Generator Sets.* (17) Mar. 5.
Foreign and American Types of Electrically-Operated Horizontal Boring-Machines.* Frank C. Perkins. (19) Mar. 5.
The Present Position of the Theory of Electrolysis. (19) Mar. 5.
Electric Lighting in the City of Benjamin Franklin.* W. C. L. Eglin. (27) Mar. 5.
The Transmission of Electric Energy Without Wires.* Nikola Tesla. (27) Mar. 5.
The Beginnings of the Incandescent Lamp.* Thos. A. Edison. (27) Mar. 5.
The Development of Industrial Electrochemistry. E. F. Roeber. (27) Mar. 5.
A Quarter Century of Electric Lighting. Louis Bell. (27) Mar. 5.
The Progress of Telegraphy During the Past Thirty Years. William Maver, Jr. (27) Mar. 5.
Expansion and Changes of Electric Light and Power Systems. Alton D. Adams. (27) Mar. 5.
A Review of Twenty-five Years of Telephony. Arthur Vaughan Abbott. (27) Mar. 5.
The First Central Station for Incandescent Lighting. W. J. Hammer. (27) Mar. 5.
The Evolution of Dynamo Design.* David B. Rushmore. (27) Mar. 5.
The Ward Leonard Single-Phase Locomotive.* G. T. Hanchett. (27) Mar. 5.
Unique Fire Alarm Switchboard on Staten Island, N. Y.* (27) Mar. 5.

Marine.

The Accident on H. M. S. *Bullfinch*.* (Breaking of connecting rod.) (11) Feb. 5.
Coaling Warships at Sea.* (22) Feb. 12.
Petrol Motors for Marine Purposes. (11) Feb. 26.
The Modern Torpedo.* (46) Mar. 5.
Le *Stephan*, Navire Poseur de Cables.* (33) Jan. 30.

Mechanical.

Apparatus for Obtaining a Continuous Record of the Position of an Engine Governor and the Speed of the Engine Which It is Governing.* Joseph C. Riley. (55) Vol. 24.
Flywheel Capacity for Engine-Driven Alternators. Walter I. Slichter, Jun. Am. Soc. M. E. (55) Vol. 24.
The Deflection of Beams by Graphics. Willibald Trinks. (55) Vol. 24.
Finer Screw Threads. Charles T. Porter, Hon. M. Am. Soc. M. E. (55) Vol. 24.
A New Oil-Testing Machine and Some of Its Results.* Albert Kingsbury, M. Am. Soc. M. E. (55) Vol. 24.
Entropy Analysis of the Otto Cycle.* Sidney A. Reeve, M. Am. Soc. M. E. (55) Vol. 24.
Rotary Pumps. John T. Wilkin, M. Am. Soc. M. E. (55) Vol. 24.
Final Report of the Committee Appointed to Standardize a System of Testing Steam Engines. (Am. Soc. M. E.) (55) Vol. 24.
Specifications for Boiler Plate, Rivet Steel, Steel Castings and Steel Forgings. (55) Vol. 24.
Test of a Hydraulic Elevator System. Reginald Pelham Bolton, M. Am. Soc. M. E. (55) Vol. 24.
Smoke Consumption: A Topical Discussion.* (55) Vol. 24.
A Method of Testing Gas Engines.* E. C. Oliver, Jun. Am. Soc. M. E. (55) Vol. 24.
Performance of an Internal Combustion Engine Using Kerosene and Gasoline as Fuel. H. F. Halladay, Jun. Am. Soc. M. E., and G. O. Hodge. (55) Vol. 24.
Tests of a Twelve-Horse-Power Gas Engine to Determine the Effects of Changes in Speed, Load, Point of Ignition, Ratio of Gas to Air, and Jacket Temperature.* C. H. Robertson, Jun. Am. Soc. M. E. (55) Vol. 24.
Some Data on Hoisting Hooks.* John L. Bacon, Jun. Am. Soc. M. E. (55) Vol. 24.
Strains Produced by Excessive Tightening of Nuts.* A. Bement, M. Am. Soc. M. E. (55) Vol. 24.
The Hot Well as an Oil Extractor.* A. H. Eldredge, M. Am. Soc. M. E. (55) Vol. 24.
Positive Governor Drives for Corliss Engines.* A. H. Eldredge, M. Am. Soc. M. E. (55) Vol. 24.
Fits and Fitting.* Stanley H. Moore, Jun. Am. Soc. M. E. (55) Vol. 24.
The Experiment Boiler of the Ohio State University.* E. A. Hitchcock, M. Am. Soc. M. E. (55) Vol. 24.
Water and Heat Consumption of a Compound Engine at Various Powers. D. S. Jacobus, M. Am. Soc. M. E. (55) Vol. 24.
Description of Sixty-Foot Vertical Boring and Turning Mill.* John Riddell, M. Am. Soc. M. E. (55) Vol. 24.

* Illustrated.

Mechanical—(Continued).

An Indicating Anglemeter.* C. E. Sargent, M. Am. Soc. M. E. (55) Vol. 24.
The Steam Turbine from an Operating Standpoint.* Fredk. A. Waldron, M. Am. Soc. M. E. (55) Vol. 24.
The Bursting of Emery Wheels.* Charles H. Benjamin, M. Am. Soc. M. E. (55) Vol. 24.
A Comparative Oil Test. William F. Parish. Jr., Jun. Am. Soc. M. E. (55) Vol. 24.
The Use of a Surveying Instrument in Machine Shop Practice.* Charles C. Tyler, M. Am. Soc. M. E. (55) Vol. 24.
Centrifugal Machines and Their Uses.* Bartholomew Viola, M. Am. Soc. M. E. (55) Vol. 24.
A Forty-Four-Foot Pit Lathe.* John M. Barnay, Jun. Am. Soc. M. E. (55) Vol. 24.
Heat Resistance, the Reciprocal of Heat Conductivity. William Kent, M. Am. Soc. M. E. (55) Vol. 24.
The Calculation of the Weight of Castings with the Aid of the Planimeter.* C. M. Schwerin. (56) Vol. 33.
The Blake Stone and Ore-Breaker: Its Invention, Forms and Modifications, and Its Importance in Engineering Industries. William P. Blake. (56) Vol. 33.
The Development of the Modern By-Product Coke-Oven.* Christopher G. Atwater. (56) Vol. 33.
Coking in Bee-Hive Ovens with Reference to Yield. Charles Catlett. (56) Vol. 33.
The Regulation of the Combustion and Distribution of the Temperature in Coke Oven Practice.* D. A. Louis. (71) Vol. 64.
Coal as Fuel at Barrow-in-Furness.* W. F. Pettigrew. M. Inst. C. E. (71) Vol. 64.
Steam Boilers for Power Plants. W. D. Chester. (58) Dec.
Foundry Costs: Their Analysis and Reduction. Henry Hess. (2) Jan.
The "Drillibite" Hand Rock-Drill.* (11) Jan. 29; (16) Feb. 11.
The Curtis Steam-Turbine.* (11) Feb. 5.
A Steam Meter.* R. S. Bayntun. (26) Feb. 5.
Notes on the Curtis Turbine.* (73) Feb. 5.
Governing Gas and Gasoline Engines. Dugald Clerk. (Paper read before the Automobile Club of Great Britain and Ireland.) (47) Feb. 6.
The Putnam 90-inch Driving Wheel Lathe.* (20) Feb. 11.
The Caskey Hydro-Pneumatic Punch.* (20) Feb. 11.
A New Vacuum System for Pneumatic Transmission.* (20) Feb. 11.
Heat Transference Through Boiler Plates.* (62) Feb. 11.
The Riedler-Stumpf Steam Turbines.* (11) Feb. 12.
Hydraulic Crane at the Tower Wharf of the General Steam Navigation Company.* (11) Feb. 12.
A New Motor Car Engine.* (12) Feb. 12; (11) Feb. 12.
Jig for Drilling and Milling.* C. T. Sutton. (12) Feb. 12.
The Steam Turbine. William Chilton. (Abstract of Paper read before the Inst. of Elec. Engrs.) (26) Serial beginning Feb. 12.
A Peculiar Explosion of Water-Tube Boilers.* John C. Higdon, Assoc. Am. Soc. M. E. (14) Feb. 13.
Boiler Scale Detection.* George J. Jones. (46) Feb. 13.
A Large Air-Cooled Petrol Motor.* (47) Feb. 13.
Water Gas. A. Humboldt Sexton. (47) Serial beginning Feb. 13.
Niagara Automatic Can Body Machine.* (20) Feb. 18.
Recent Developments in Gas Engines. D. S. Capper, M. Inst. C. E. (Abstract of Paper read before the Junior Inst. of Engrs.) (62) Feb. 18.
Pneumatic-Power Hammers.* (11) Feb. 19.
The Crystal Palace Motor Car Show.* (12) Serial beginning Feb. 19; (11) Feb. 19.
Compound Horizontal Engine. (12) Feb. 19.
The Grinding Machine *v.* the Lathe. (12) Feb. 19.
New Cement Works at Portland, Colo.* James D. Schuyler. (14) Serial beginning Feb. 20.
Efficiency Test of 1 250-K. W. Steam Turbine for Interborough Company, New York City.* A. M. Mattice. (27) Feb. 20.
Milling Machines. Thomas R. Shaw.* (47) Serial beginning Feb. 20.
A Novel System of Air Compressing.* (47) Feb. 20.
Valve Mechanism for Blowing Engines.* (47) Feb. 20.
A Turbo-Electric Wagon.* (47) Feb. 20.
The Use of Copper in Engineering Practice. W. Ed. Storey. (47) Serial beginning Feb. 20.
Care of Benches and Results Therefrom. T. J. Whalen. (Paper read before the Mich. Gas Assoc.) (24) Feb. 22.
Standard Specifications for Cast Iron Pipe and Special Castings. (Proposed by Committee B of the International Assoc. for Testing Materials.) (20) Feb. 25; (24) Mar. 7.
Motor Car Tires and Springs.* J. S. V. Bickford. (12) Feb. 26.
Water-Tube Boiler. (12) Feb. 26.
A New Die Head.* (12) Feb. 26.
The Works of Graham, Morton, and Co., Limited.* (12) Feb. 26.
Small Gas Engines *v.* Electric Motors. (26) Feb. 26.
Turbines and Superheated Steam. W. H. Booth. (26) Feb. 26.
Comparison of Different Types of Calorimeter. J. S. S. Brame and Wallace A. Cowan. (From the *Journal* of the Soc. of Chem. Industry.) (22) Feb. 26.

---

* Illustrated.

Mechanical—(Continued).

Superheated Steam. G. D. Seaton. (Abstract of Paper read before the Staffordshire Iron and Steel Inst.) (22) Feb. 26.
Notes on the Curtis Turbine.* F. Samuelson. (Abstract of Paper read before the Rugby Eng. Soc.) (26) Serial beginning Feb. 26.
Westinghouse Gas Engines.* (26) Feb. 26.
An Allen High-Speed Triple Expansion Engine. (73) Feb. 26.
The Brush-Parsons Steam Turbine.* William Chilton. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Feb. 26.
British Association Small Screw Gauge Committee: Report.* (73) Feb. 26.
American Designs of Gas and Oil Engines.* (47) Serial beginning Feb. 27.
Producer Gas.* A. Humboldt-Sexton. (47) Serial beginning Feb. 27.
Tests of High-Speed Tool Steels. (18) Feb. 27.
The Pielock Superheater System.* (18) Feb. 27.
The Laying of High and Low Pressure (River) Gas Lines.* H. C. Morris. (Paper read before the Mich. Gas Assoc.) (24) Feb. 29.
The Laying of Mains and Services and the Recording of Same. John Hellen. (Paper read before the Mich. Gas Assoc.) (24) Feb. 29.
Lubricating Oils and Their Properties: How to Test Them and Detect Adulterations.* William M. Davis. (64) Mar.
Drum-Head Casing for Flywheels.* E. E. Clock. (64) Mar.
Further Details of the Cockerill Gas Engine.* (64) Mar.
Burning Powdered Coal.* H. J. Travis. (64) Mar.
Link Motions as Applied to Rolling Mill Engines.* (64) Mar.
Cost Chart for Steam and Gas Power Plants. J. R. Bibbins. (64) Mar.
Methods and Results of Shop-Testing of Steam Turbines.* J. R. Bibbins, Assoc. Am. Inst. E. E. (13) Mar. 3.
Safety Devices for Hydraulic Plants. Frank B. Kleinhans, M. Am. Soc. M. E. (13) Mar. 3.
A Pressed Steel Shaft Hanger.* (20) Mar. 3.
The Morgan 1½-inch Single Bolt Threader.* (20) Mar. 3.
A New Heavy Boring Lathe with Hydraulic Feed.* (20) Mar. 3.
Capitaine's Crank-Pin Turning Machine.* (15) Mar. 4.
Some New Details of the Reeves Steam Engine.* (14) Mar. 5.
La Fabrication Mécanique des Tuiles en Provence.* H. Degeay. (36) Serial beginning Jan. 25.
Véhicules Automobiles Lourds, à Pétrole ou à Vapeur.* L. Pierre-Guédon. (34) Serial beginning Feb.
Chauffage aux Combustibles Liquides.* (34) Feb.
Causes d'Explosion des Valves en Fonte des Conduites de Vapeur.* Sylvain Périssé. (33) Feb. 6.
Les Progrès de l'Automobilisme en 1903: Les Principales Épreuves de l'Année. F. Drouin. (33) Serial beginning Feb. 13.

Metallurgical.

The Reactions of the Ziervogel Process and Their Temperature-Limits.* Robert Henry Bradford. (56) Vol. 33.
The Effect of Re-Heating upon the Coarse Structure of Over-Heated Steel. K. Frederik Göransson. (56) Vol. 33.
The Direct Cyaniding of Wet-Crushed Ores in New Zealand. Hamilton Wingate. (56) Vol. 33.
Notes on the Treatment of Zinc-Precipitate Obtained in Cyaniding New Zealand Ore. Hamilton Wingate. (56) Vol. 33.
Truck-Support for Furnace-Bottoms.* Henry A. Mather. (56) Vol. 33.
The Camp Bird Mill. Thomas H. Woods and Godfrey D. Doveton. (56) Vol. 33.
Puddled Iron and Mechanical Means for Its Production.* James P. Roe. (56) Vol. 33.
The Elimination of Arsenic, Antimony and Bismuth from Copper. Allan Gibb. (56) Vol. 33.
An "All-Fire" Method for the Assay of Gold and Silver in Blister-Copper. Walter G. Perkins. (56) Vol. 33.
Specifications for Steel Forgings and Steel Castings. William R. Webster. (56) Vol. 33.
The Development of the Bessemer Process for Small Charges. Bradley Stoughton. (56) Vol. 33.
The Effect of Tellurium on Brass. Erwin S. Sperry. (56) Vol. 33.
Amarillium. William M. Courtis. (56) Vol. 33.
Diseases of Steel. C. H. Ridsdale. (71) Vol. 64.
Note on the Manufacture of Weldless Steel Pipes and Shells. Heinrich Ehrhardt. (71) Vol. 64.
The Influence of Silicon on Iron.* Thomas Baker. (71) Vol. 64.
Some Further Experiments on the Diffusion of Sulphide through Steel.* E. D. Campbell. (71) Vol. 64.
Notes on the Heat Treatment of Steel Rails High in Manganese. J. S. Lloyd. (71) Vol. 64.
The Heat Treatment of Steel.* William Campbell. (A report on research carried out during 1902.) (71) Vol. 64.
The Burning and Overheating of Steel.* Alfred Stansfield. (71) Vol. 64.

* Illustrated.

Metallurgical—(Continued).

The Briquetting of Iron Ore. A. Weiskopf. (Paper read before the Min. and Metal. Cong. at Vienna.) (71) Vol. 64.
Alloys of Iron and Tungsten.* R. A. Hadfield. (71) Vol. 64.
The Restoration of Dangerously Crystalline Steel by Heat Treatment.* J. E. Stead and Arthur W. Richards. (71) Vol. 64.
Sorbitic Steel Rails.* J. E. Stead and Arthur W. Richards. (71) Vol. 64.
Proportions of Regenerative Gas Furnaces, with Special Reference to Open-Hearth Furnaces.* H. D. Hess. (2) Jan.
Magnetic Tests of Whole Sheets of Iron.* (11) Jan. 29.
The Minnequa Works of the Colorado Fuel and Iron Company.* (22) Jan. 29.
A Trapezoidal Slimes Agitator.* Courtenay De Kalb. (16) Feb. 11.
Edwards' Mechanical Ore-Roasting Furnace.* F. Danvers Power. (16) Feb. 11.
Metallurgy as Applied in Engineering. Archibald P. Head, M. Inst. C. E. (Address delivered to the Students of the Inst. of Civ. Engrs.) (11) Feb. 12.
Alumino-Thermics and Its Uses for Welding and Metallurgical Purposes.* (15) Feb. 12.
Thermit: Its Application to Metallurgical Engineering. C. V. Boys. (29) Feb. 12.
Dissolved Oxide in Cast Iron. (47) Feb. 13.
The Wanner Pyrometer.* (20) Feb. 18.
Ferronickel Direct from Pyrrhotite.* Ernst A. Sjöstedt. (Paper read before the New England Foundrymen's Assoc.) (20) Feb. 18.
The Semi-Solid State in Metals. Thomas Turner. (Paper read before the Staffordshire Iron and Steel Inst.) (62) Serial beginning Feb. 18.
Alloys of Iron and Steel. R. A. Hadfield. (47) Feb. 20.
The Determination of Gold in Cyanide Solutions. A. Prister. (Abstract from Paper in the *Journal* of the Chem., Metal. and Min. Soc. of S. Africa.) (16) Feb. 25.
Standard Specifications for Cast Iron Pipe and Special Castings. (Proposed by Committee B of the International Assoc. for Testing Materials.) (20) Feb. 25; (24) Mar. 7.
Recent Investigations in Cast Iron. Alexander E. Outerbridge. (62) Feb. 25.
Steel Castings. C. W. Gennet, Jr. (15) Feb. 26.
Improved Metal Melting Furnaces.* (47) Feb. 27.
An Automatic Temperature Detector for Rolled Steel.* (47) Feb. 27.
A Method for the Direct Determination of Alumina. Chas. E. Rueger. (16) Mar. 8.
The Payne-Gillies Copper Process. F. Danvers Power. (16) Mar. 8.
La Résistance Électrique des Fers et Aciers. (33) Feb. 6.

Mining.

Determining the Size of Hoisting-Plants.* Edward B. Durham. (56) Vol. 33.
Notes on the Cost of Hydraulic Mining in California. W. E. Thorne. (56) Vol. 33.
The Valuation of Mines of Definite Average Income. H. D. Hoskold. (56) Vol. 33.
The Gold-Field of the State of Minas Geraes, Brazil.* (56) Vol. 33.
The Camp Bird Mine, Ouray, Colorado: Mining and Ore-Transportation.* Chester Wells Purington. (56) Vol. 33.
The Manganese Industry of the Department of Panama, Republic of Columbia.* E. G. Williams. (56) Vol. 33.
The Mining Industry of the Cœur d'Alenes, Idaho.* J. R. Finlay. (56) Vol. 33.
Pumping Plant at the Miike Collieries, Japan.* (11) Jan. 29.
Compound Winding Engine at Sherwood Colliery.* Charles H. Heathcote. (22) Jan. 29.
An Improved Haulage Clip.* (57) Jan. 29.
Report of the Electricity in Mines Committee. (57) Feb. 5; (22) Feb. 5.
Anthracite Mine Surveying Practice. (16) Feb. 11.
Electrical Winding Engines.* R. Herzfeld. (11) Feb. 12.
Electric Haulage in Metal Mines. W. N. Clark. (To be read before the Tech. and Eng. Soc., State School of Mines, Colorado.) (16) Feb. 25.
Mechanical Slate-Pickers.* (16) Feb. 25.
Electric Haulage Underground. George Farmer. (Paper read before the Nat. Assoc. of Colliery Mgrs.) (22) Feb. 26.
The Mechanical Equipment of Collieries. George H. Winstanley. (Abstract of Paper read before the Manchester Geol. and Min. Soc.) (22) Feb. 26.

Miscellaneous.

Drawing Office Equipment.* John McGeorge. (55) Vol. 24.
Report of Committee Appointed to Discuss the Arguments in Favor of and Against the Metric System. (Am. Soc. M. E.) (55) Vol. 24.
A Rational Solution of the Problem of Weights and Measures. Sidney A. Reeve, M. Am. Soc. M. E. (55) Vol. 24.
The Metric System. F. A. Halsey, M. Am. Soc. M. E. (55) Vol. 24.
L'Exposition Universelle de Saint-Louis en 1904.* Hugues Brussel. (33) Feb. 20.

Municipal.

Concrete Foundation and Cement Filler for Brick Pavement. O. L. Gearhart. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (60) Mar.; (14) Feb. 13.
Maintenance of Asphalt Pavements in Washington, D. C. H. C. Newcomer. (13) Feb. 18.
Road Making in Buxton, England.* John Hattan. (60) Mar.
The Philadelphia Gas Engine Pumping Station for Fire Service.* (14) Mar. 5.
Pompe à Incendie Automobile.* F. Drouin. (33) Feb. 6.

* Illustrated.

in Resistance Formula. John Balch Blood, Assoc. M. Am. Soc. M. E.

ils.* J. E. Stead and Arthur W. Richards. (71) Vol. 64.
eat Treatment of Steel Rails High in Manganese. J. S. Lloyd. (71)

Investigation into the Stresses and Strains in Axles and Wheels in
B. Bissell. (65) Jan. 15.
e of Charcoal Iron Railway Boiler Tubes.* Geo. G. Crawford. (61)

alanced Compound Locomotives.* A. von Borries. (12) Jan. 29.
ate Owners' Wagons.* (21) Feb.
Atlantic" Engines: North Eastern Railway.* (21) Feb.
r Car: Taff Vale Railway.* (21) Feb.
-Point Lock and Detector.* (21) Feb.
acity Coal Cars: Chicago, Milwaukee & St. Paul Railway.* (39) Feb.
und Locomotive: Great Western Railway of England.* (39) Feb.
st Device, C. G. W. Ry.* (39) Feb.
ents of the Chicago, Milwaukee & St. Paul Railway at West Milwaukee.*

Box.* (39) Feb.
f a Modern Railway Paint Shop. W. O. Quest. (39) Serial beginning

he C., R. I. & P. Ry. at East Moline, Ill.* (18) Feb. 6.
Car, Central R. R. of N. J.* (18) Feb. 6.
Superheater for the Saxony State Railways.* Charles R. King. (47)

way Signalling. (12) Serial beginning Feb. 12.
on Coke Car.* (15) Feb. 12.
Journal-Box with Outside Dust Guard.* (15) Feb. 12.
omobile Train.* (40) Feb. 12.
lericksburg & Potomac Revision.* (40) Feb. 12.
ress Locomotive for India.* (40) Feb. 12.
is Central Yard Construction.* (40) Feb. 12.
isco, Oakland & San José Railway: "The Key Route."* (17) Serial
eb. 13.
k Signals, C., C. & L. R. R.* (18) Feb. 13.
ral Pacific Type Locomotives.* (18) Feb. 13.
ia R. R. Exhibit at the Louisiana Purchase Exposition. (18) Feb. 13.
portion.* F. K. Caswell. (18) Feb. 13.
ve as a Detriment to the Successful Operation of a Locomotive. G. W.
stract of Paper read before the St. Louis Ry. Club.) (18) Feb. 13.
inder Compound Locomotive.* (47) Feb. 13.
Cleaning Plant for Gravel Ballast.* (13) Feb. 18.
ning, Parlor and Day Cars.* (13) Feb. 18.
Some Engineering Approximations; Formulas for Elevation of Outer
ves. W. D. Taylor, M. Am. Soc. C. E. (13) Feb. 18.
ger Locomotive for the North-Eastern Railway.* (11) Feb. 19.
e Experiments. Charles Rous-Marten. (12) Feb. 19.
e Caledonian Railway of Scotland.* (15) Feb. 19.
l Frame Tank Car.* (15) Feb. 19.
ndling Locomotives at Terminals. Charles H. Fry. (15) Feb. 19.
k Signals and Interlocking on the New York & Long Branch Railroad.*
.
auge of the National Railroad of Mexico. J. L. Bothwell. (14) Feb. 20.
l Ventilation.* (14) Feb. 20.
he Terminal Railroad of St. Louis.* (18) Feb. 20.
Tenders. David Van Alstyne. (Paper read before the Iowa Ry. Club.)
.
nomical Load for a Locomotive. Chas. T. Noyes. (Abstract of Paper
the Pacific Coast Ry. Club.) (18) Serial beginning Feb. 20.
ork on the Southern Indiana Railway.* (13) Feb. 25.
Use of Block Signals.* (15) Feb. 26.
Automatic Signals in Cold Weather. H. S. Balliet. (15) Feb 26.
ndhouses.* (15) Feb. 26.
Saint Louis Terminal Station.* (40) Feb. 26.
e Shops of the Rock Island.* (40) Feb. 26.
ing Competitive Tests of Capacity, Power Consumption and Efficiency
iven Compressors for Brake Service. Edward H. Dewson. (17) Feb. 27.
gine, Union Pacific R. R.* (18) Feb. 27.
ctric Railway Company's System.* (17) Serial beginning Feb. 27.
or Cast Iron Car Wheels. (18) Feb. 27.
Electro-Gas Signals on the North-Eastern Railway. (18) Feb. 27.
ests of Brake Beams: Steel vs. Wooden Beams. (25) Mar.
assenger Locomotives: 4-6-2 (Pacific) Type, N. Y. C. & H. R. R. R.*

---

* Illustrated.

Railroad—(Continued).

A Comparison of Circular and Rectangular Engine Houses. (13) Mar. 3.
The Influence of Railroads on Latin-American Stability. Edward P. North, M. Am. Soc. C. E. (15) Mar. 4.
Fuel Tests on the Furness Railroad. England. (15) Mar. 4.
New Cars for the Milwaukee Refrigerator Transit Company.* (15) Mar. 4.
The Improvements on the Big Four Line between Lawrenceburg Junction and Sunman.* (14) Mar. 5.
The Construction of the Texas & Oklahoma Railroad.* Robert F. Powell. (14) Mar. 5.
The Grand Central Depot Yard Improvements, New York.* (14) Mar. 5.
Air Brake for Electric Railways.* (17) Mar. 5.
The Great Northern & City Railway.* (17) Mar. 5.
Terminals at the St. Louis Exposition.* (17) Mar. 5.
Electricity as a Substitute for Steam in Heavy Railroad Service. Arthur M. Waitt. (40) Mar. 4.
Block Signals. A. M. Schoyer. (Paper read before the Ry. Club of Pittsburg.) (40) Mar. 4; (18) Mar. 5.
Consolidation Locomotive for Southern Railway.* (40) Mar. 4.
Baldwin Atlantic Type Compound Locomotive, C. M. & St. P. Ry.* (18) Mar. 5.
The Relief Valve in Locomotive Operation. (18) Mar. 5.
Steam Economy in the Locomotive. J. B. Alfree. (Paper read before the St. Louis Ry. Club.) (18) Mar. 5.
European Electrically Operated Car Transporters.* Frank C. Perkins. (18) Mar. 5.
A New Type of Rail.* (19) Mar. 5.
Les Voitures Automotrices de Chemins de Fer à Vapeur et à Pétrole.* L. Turgan. (32) Nov.
Etude des Mouvements Secondaires sur les Véhicules en Marche.* M. Sabouret. (38) Feb.
Note sur les Essais Effectués en Service Courant et à l'Aide d'Indicateurs de Pression sur les Locomotives Compound à 2 Cylindres et à 6 Roues Accouplées de la Compagnie du Midi.* Marchis et Ménétrier. (38) Feb.
Tunnel Fondé sur Pieux à Vis de Pennsylvania and Long-Island Railroad.* (33) Feb. 6.
Ascenseurs du Central London Railway: Ascenseurs Hydrauliques de la Station de Shepherd's Bush. (33) Feb. 20.

Railroad, Street.

Notes on the Construction of an Electric Road and Power-House at Morgantown, West Virginia.* Walter Loring Webb. (2) Jan.
Development of the Brill System of Trucks for Electric Motor Cars.* Wm. H. Heulings, Jr. (2) Jan.
"Tangential" Traction.* (73) Jan. 29.
A Tramways Telephone System.* (73) Jan. 29.
Conduit Permanent Way for Tramways.* (21) Feb.
Steam Cars for Public Service.* Thomas Clarkson, M. I. Mech. E. (29) Feb. 5.
A Single-Phase Electro-Pneumatic Railway System.* Bion J. Arnold. (73) Feb. 5.
The Electrification of the Metropolitan Railway.* (12) Serial beginning Feb. 12.
The Street Railway System of Schaffhausen, Switzerland.* (17) Feb. 13.
Steel Car for the New York Subway.* (17) Feb. 13.
New Surface Contact System.* (17) Feb. 13.
Interborough Rapid Transit All-Steel Cars.* (40) Feb. 19.
Manchester Street Power Station of the Rhode Island Company, Providence.* (14) Serial beginning Feb. 20.
Westinghouse No. 91 Single-Phase Railway Motor.* (17) Feb. 20.
Railway Power Plant at Providence, R. I.* (17) Feb. 20.
An Experimental Electric Railroad.* (19) Feb. 20.
The Lamme Single-Phase Railway Motor.* (27) Feb. 20.
Manchester Corporation Tramways: The Permanent Way, Overhead Equipment and Rolling Stock. J. M. McElroy. (Abstract of Paper read before the Inst. of Elec. Engrs.) (26) Feb. 26.
The Barking-Becton Light Railway.* (73) Feb. 26.
Special Pneumatic Lock for the Harlem River Tunnel.* (14) Feb. 27.
The Alternating Railway Motor Situation. Louis Bell. (17) Feb. 27.
Rail Joints and Their Relation to Pavements. C. R. Van Buskirk. (Paper read before the Brooklyn Engineers' Club.) (17) Feb. 27.
Efficiency Test of 1 250 Kilowatt Steam Turbine for Interborough Rapid Transit Company, New York City.* A. M. Mattice. (64) Mar.
Fireproof Cars for New York Subway.* (25) Mar.; (15) Feb. 12.
A Proposed Solution of the Brooklyn Bridge Terminal Problem.* S. S. Neff. (13) Mar. 3.
Erection of the Westchester Elevated Railway.* (14) Mar. 5.
Section Five A, Second Division, New York Rapid Transit Railroad.* (14) Mar. 5.
The New York and Brooklyn Tunnel for the Rapid Transit Railroad.* (14) Serial beginning Mar. 5.
Pneumatic Station Indicator for Subway and Elevated Systems.* (17) Mar. 5.
New Cars for Detroit.* (17) Mar. 5.

---

* Illustrated.

Railroad, Street—(Continued).

New K-28 Controller for the St. Louis Transit Company.* (17) Mar. 5.
The Manx Electric Railway.* (17) Mar. 5.
The Tramway System of Bath, England.* (17) Mar. 5.
The Fused Steel-Tired Wheel.* Knox Taylor. (17) Mar. 5.
Cast-Welded Joints. Albert B. Herrick. (17) Mar. 5.
Automatic Railway Switch.* (17) Mar. 5.
The First Commercial Electric Street Railway in America.* (27) Mar. 5.
Past, Present and Future of Electric Traction. Frank J. Sprague. (27) Mar. 5.
The Ward Leonard Single-Phase Locomotive.* G. T. Hanchett. (27) Mar. 5.
Great Northern & City Railway, London, England.* (27) Mar. 5; (73) Jan. 29.
Appareil de Sécurité "Schulz" pour Tramways Électriques à Trolley avec Fil Protecteur.* (36) Feb. 10.

Sanitary.

The Sanitation and Proposed Sewerage System of Havana, Cuba. A. E. Carter, Assoc. M. Am. Soc. C. E. (6) Nov.
The Allegheny River; A Bacteriological Problem. W. H. Ingram. (58) Dec.
Sewage Testing Apparatus.* (12) Feb. 12.
Some Recent Small Sewage Purification Plants.* W. S. Shields. (Abstract of Paper read before the Indiana Eng. Soc.) (14) Feb. 13.
A Novel Center and Form for Concrete Sewer Work.* (13) Feb. 18.
Typhoid Fever History and the Water Supply of Pittsburg, Allegheny and Vicinity.* (13) Feb. 25.
Extension of the London Main Drainage System. (12) Feb. 26.
A Small Wood-Stave Outfall Sewer at New London.* (14) Feb. 27.
The Sewage Purification Plant at the Eastern Hospital for the Insane.* R. L. Sackett. (Abstract of Paper read before the Indiana Eng. Soc.) (60) Mar.
An Epidemic of Typhoid Fever in East Minneapolis. Frederic H. Bass. (13) Mar. 3.
Construction of a Joint Trunk Sewer System in the Valleys of the Rahway and Elizabeth Rivers, New Jersey.* (14) Mar. 5.

Structural.

The Siegwart Ferro-Concrete Floor Beams.* (11) Jan. 29.
The Record of the Fire-Proof Building in the Baltimore Conflagration.* (13) Feb. 18.
Concerning the Failures of Reinforced Concrete.* (13) Feb. 18.
Detailed Studies of Fireproof Buildings in the Baltimore Conflagration.* (13) Feb. 25.
Steel Structures in the Baltimore Fire.* (20) Feb. 25; (14) Feb. 20.
The Cost of Raw Materials in Cement Manufacture. Morris M. Green. (62) Feb. 25.
Details of the Large Timber Roof of a Public Shelter in Van Cortlandt Park, New York.* (14) Feb. 27.
A Central Heating, Lighting and Ice-Making Station, Gulfport, Miss.* (14) Feb. 27.
Concrete Masonry with Special Reference to the Use of Natural Bank Gravel. George S. Pierson, M. Am. Soc. C. E. (Abstract of Paper read before the Mich. Eng. Soc.) (60) Mar.
Concrete. S. B. Newberry. (Abstract of Paper read before the Indiana Eng. Soc.) (60) Mar.
The "Slot System" of Attaching Shaft Hangers and Fixtures to Concrete-Steel Structures.* Henry Parsons Jones. (13) Mar. 3.
Caisson Foundations for a Large Steel-Cage Office Building on Broadway, New York.* (14) Mar. 5.
Concrete Plant for the New Union Depot, Washington.* (14) Mar. 5.
Difficulties and Methods of Plastering in Winter. D. L. Haigh. (14) Mar. 5.
Works of the Smith Premier Typewriter Company, Syracuse.* (14) Serial beginning Mar. 5.
The Erection of the Wall Street Exchange Building, New York.* (14) Mar. 5.

Topographical.

Massachusetts Institute of Technology Tape Apparatus. (14) Feb. 27.

Water Supply.

Turbine Flow-Recorder.* C. M. Allen, Jun. Am. Soc. M. E. (55) Vol. 24.
An Analysis of the "Commercial" Value of Water-Power per Horse-Power per Annum. A. F. Nagle, M. Am. Soc. M. E. (55) Vol. 24.
Water Softening.* James O. Handy. (58) Dec.
Illustrated Description of Some Filter Plants and Results.* Morris Knowles. (58) Dec.
Open or Covered Filters? Frans Engstrom. (58) Dec.
The Allegheny River; A Bacteriological Problem. W. H. Ingram. (58) Dec.
An American Hydro Electric Power Plant.* (12) Jan. 29.
New Type of Purifying Plant: Industrial Water Company.* (15) Feb. 12.
New Design of Water Softener.* (40) Feb. 12.
Power Development of the Toronto & Niagara Power Company.* (14) Feb. 13.
A New Water Power Development at New Milford, Connecticut.* Walter Scott Morton. (14) Serial beginning Feb. 13.
High-Pressure Power on the Housatonic.* (27) Feb. 13.

* Illustrated.

ly—(Continued).

d Tunnel for Water Development for Santa Barbara, Cal. (13) Feb. 18.
d Feed Pump.* (11) Feb. 19.
and History of the Water-Works and the American System of Filtration at
Austria.* E. A. Gieseler. (14) Feb. 20.
ning Plants for the C., R. I. & P. Ry.* (18) Feb. 20.
er History and the Water Supply at Pittsburg, Allegheny and Vicinity.*
. 25.
er Plant for the New Chester Water Company.* (14) Feb. 27.
nd Steel Covered Reservoir for Hoylake and West Kirby Water Works,
(14) Feb. 27.
ying Plant.* (18) Feb. 27.
allation of Water-Softening Apparatus for the Rock Island.* (25) Mar.
High Pressure Water Supply System for Fire Protection in Chicago.* (13)

of Typhoid Fever in East Minneapolis. Frederic H. Bass. (13) Mar. 3.
Loch Raven, Baltimore.* Alfred M. Quick. (14) Mar. 5.
the Wachusett Dam of the Metropolitan Water-Works, Massachusetts.*
. 5.
teel-Construction Filtration Plant for the New Haven Water Company.*
al beginning Mar. 5.
phia Gas Engine Pumping Station for Fire Service.* (14) Mar. 5.
érale du Mouvement Varié de l'Eau dans les Tuyaux de Conduite. E.
(37) Serial beginning Jan. 31.
e la Roche Calcaire des Environs de Tournai.* Ch. François. (30) Feb.

f-Shore Floating Dock for the Reiherstieg Schiffswerfte und Maschinenfa-
nburg.* (11) Feb. 12.
t Delfzijl.* (12) Feb. 19.
rg Harbor and the Yazoo River Diversion Canal. Walter H. Polk. (14)

Southwest Pass of the Mississippi a Ship Channel.* (19) Feb. 20.
chinery for the New Dock at Chatham.* (11) Feb. 26.
lage on the Teltow Canal.* (17) Mar. 5.
a Commission Néerlando-Belge Chargée de Visiter des Installations dans le
l'étranger en Vue de l'Outillage à Adopter pour la Manœuvre Mécanique
à Construire a Terneuzen.* (30) Serial beginning Feb.

---

* Illustrated.

AMERICAN S

OF

CIVIL ENGI

April, 1904

PROCEEDINGS - VO

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

Published at the House of the Society, 220 Wes
the Fourth Wednesday of each Month

Entered as Second-Class Matter at the New York

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXX. No. 4.

APRIL, 1904.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1904.

American Society of Civil Engineers.

OFFICERS FOR 1904.

President, CHARLES HERMANY.

Vice-Presidents.

Term expires January, 1905:
L. F. G. BOUSCAREN,
JAMES D. SCHUYLER.

Term expires January, 1906:
F. S. CURTIS,
S. L. F. DEYO.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1905:
RICHARD S. BUCK,
GEORGE H. PEGRAM,
WILLIAM J. WILGUS,
WILLIAM JACKSON,
EDMUND F. VAN HOESEN,
JAMES L. FRAZIER.

Term expires January, 1906:
ALFRED CRAVEN,
JOSEPH O. OSGOOD,
GEORGE S. DAVISON,
E. C. LEWIS,
HUNTER McDONALD.
ELWOOD MEAD.

Term expires January, 1907:
CHARLES S. GOWEN,
NELSON P. LEWIS,
JOHN W. ELLIS,
GEORGE S. WEBSTER.
RALPH MODJESKI.
CHARLES D. MARX.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:
S. L. F. DEYO,
L. F. G. BOUSCAREN,
RICHARD S. BUCK,
WILLIAM J. WILGUS,
CHARLES S. GOWEN.

On Publications:
GEORGE H. PEGRAM,
ALFRED CRAVEN,
JOSEPH O. OSGOOD,
GEORGE S. DAVISON,
HUNTER McDONALD.

On Library:
NELSON P. LEWIS,
WILLIAM JACKSON,
E. C. LEWIS,
RALPH MODJESKI,
CHARLES WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—L. F. G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 588 Columbus.
CABLE ADDRESS, - - - - "Ceas, New York."

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

April 6th, 1904.—The meeting was called to order at 8.40 P. M.; Alfred Craven, Director, in the chair; Chas. Warren Hunt, Secretary; and present, also, 132 members and 46 guests.

The minutes of the meetings of March 2d and 16th, 1904, were approved as printed in the *Proceedings* for March, 1904.

The paper for the evening, entitled "A Phenomenal Land Slide," by D. D. Clarke, M. Am. Soc. C. E., was read by title, and the Secretary presented a letter relating to the present condition of the work described, written by the author since the paper was published.

G. B. Francis, M. Am. Soc. C. E., gave a description of the re cently constructed Lackawanna and Wyoming Valley, double-track third-rail, electric railroad from Scranton to Wilkesbarre, Pa., illus trated with lantern slides.

The Secretary announced that a contract had been signed for th purchase by the Society of the lot, 25 by 116 ft., to the west of th Society House.

Ballots for membership were canvassed, and the following candi dates elected:

As MEMBERS.

LUTHER ELWOOD GREGORY, Portsmouth, N. H.
GEORGE TERRY HORTON, Chicago, Ill.
EDGAR S NETHERCUT, Chicago, Ill.
WILLIAM NEWBROUGH, Evanston, Wyo.
STEWART KEDZIE SMITH, Billings, Mont.
GUSTAV ADOLPH TRETTER, Phœnixville, Pa.
COLIN REED WISE, Passaic, N. J.

As ASSOCIATE MEMBERS.

ARTHUR ADAMS, Utica, N. Y.
DANIEL EDWARDS BRINSMADE, Derby, Conn.
JOSIAH WILLIAM BUZZELL, Boston, Mass.
FRANCIS ALBERTSON COKEFAIR, Duluth, Minn.
WILLIAM ROBERT DUNN, Easton, Pa.
FRANK LEWIS FALES, Cincinnati, Ohio.
WILLIAM OTTO GALBREATH, San José, Tamaulipas, Mexico.
ERNEST ROTTECK GAYLER, New London, Conn.
FRED MAY GREEN, New York City.
THEODORE JULIUS KLOSSOWSKI, Ottawa, Ont., Canada.
BURTON RUTHERFORD LEFFLER, Cleveland, Ohio.
LUTHER HAMMOND LEWIS, New York City.
THOMAS EUGENE LEARD LIPSEY, Beaver, Pa.
WILLIAM SEELEY LOGAN, Arlington, N. J.
WILLIAM SMITH MORISON, Pennsgrove, N. J.
CLARENCE HICKS NICHOLS, New York City.
CLARENCE WEBSTER RAYNOR, Kansas City, Mo.
DEWITT LEE REABURN, Washington, D. C.
LLOYD BOWN SMITH, Arkansas City, Ark.
HERBERT JOSEPH WILD, Meriden, Conn.
WALTER SCOTT WILLIAMS, Columbia, Mo.
WINTHROP BARRETT WOOD, Providence, R. I.

As Associate.

Alcide Chaussé, Montreal, Que., Canada.

The Secretary announced the transfer of the following candidates, by the Board of Direction, on April 5th, 1904, from the grade of Associate Member to the grade of Member:

As Members.

Ralph Hamilton Chambers, New York City.
James Rutherford Elliott, Pittsburg, Pa.
Walter Joseph Francis, Peterborough, Ont., Canada.
Julius Herman George Wolf, San Francisco, Cal.

The Secretary announced the election of the following candidates, by the Board of Direction, on April 5th, 1904:

As Juniors.

Arthur Henry Birks, Phœnixville, Pa.
Lorenzo Dana Cornish, Beaver, Pa.
Frederick Van Zandt Lane, Mt. Vernon, N. Y.
Justin Wyman Ludlow, Chicago, Ill.
Alfred Wheeler Roberts, Jersey City, N. J.
Harry Ashton Roberts, Hoboken, N. J.
George Loomis Robinson, New York City.
Oswald Procter Shelley, Cornwall, Cal.

Adjourned.

April 20th, 1904.—The meeting was called to order at 8.50 p. m., George H. Pegram, Director, in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 120 members and 27 guests.

A paper, entitled "Lateral Earth Pressure and Related Phenomena," by E. P. Goodrich, Jun. Am. Soc. C. E., was presented by the author. A communication on the subject from M. F. Bonzano, M. Am. Soc. C. E., was presented by the Acting Secretary, and the paper was discussed by Messrs. R. B. Stanton, Richard Lyman, Virgil H. Hewes, H. F. Dunham and the author.

The Acting Secretary announced the death of the following members:

Henry Louis Marindin, elected Member May 7th, 1884; died March 25th, 1904.

B. Frank Richardson, elected Member July 1st, 1885; died April 18th, 1904.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

April 5th, 1904.—8.40 P. M.—President Hermany in the chair; Chas. Warren Hunt, Secretary, and present, also, Messrs. Buck, Craven, Croes, Curtis, Davison, Deyo, Ellis, Gowen, Jackson, Knap, E. C. Lewis, N. P. Lewis, Modjeski, Noble, Osgood, Pegram, Webster, and Wilgus.

Resolutions were adopted authorizing the purchase of a lot, 25 ft. front, with an average depth of 116 ft., immediately adjoining the present Society House.

The Secretary was authorized to open and count the ballots on the proposed Committee on "Concrete and Steel-Concrete," and to report the result to the next meeting of the Board.

Applications were considered and other routine business transacted.

Four Associate Members were transferred to the grade of Member, and eight candidates for Junior were elected.*

Adjourned.

---

* See page 167.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, May 4th, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Lake Cheesman Dam and Reservoir," by Charles L. Harrison, M. Am. Soc. C. E., and Silas H. Woodard, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for March, 1904.

Wednesday, May 18th, 1904.—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "The Gatun Dam," by C. D. Ward, M. Am. Soc. C. E.; and "The Collapse of a Building During Construction," by H. de B. Parsons, M. Am. Soc. C. E.

Both these papers are printed in this number of *Proceedings*.

Wednesday, June 1st, 1904.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, "On Sedimentation," by Allen Hazen, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo., during the week beginning October 3d, 1904.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an engineering exhibit, and the establishment of Headquarters for visiting engineers, and the Board of Direction has appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

ROBERT MOORE, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
EDWARD C. CARTER, M. Am. Soc. C. E., Chicago, Ill.
MORDECAI T. ENDICOTT, M. Am. Soc. C. E., Washington, D. C.
JAMES L. FRAZIER, " " Frankfort, Ind.
WILLIAM JACKSON, " " Boston, Mass.
EMIL KUICHLING, " " New York, N. Y.
J. L. VAN ORNUM, " " St. Louis, Mo.
JOHN F. WALLACE, " " Chicago, Ill.
O. E. MOGENSEN, *Sec'ty*, " " St. Louis, Mo.

INTERNATIONAL ENGINEERING CONGRESS.

The following list gives the names of engineers who, by special invitation of the Committee in Charge, have promised to review the development of engineering practice in their respective countries during the past ten years.

HARBORS.—*Subject No. 1:*

W. MATTHEWS, C. M. G., M. Inst. C. E., Chief Engr. of Dover Harbor, England.

V. E. TIMONOFF, M. Am. Soc. C. E., St. Petersburg, Russia.

On The Great Lakes.

DAN C. KINGMAN, Maj., Corps of Engrs., U. S. A.

D. D. GAILLARD, Capt., Corps of Engrs., U. S. A.

On The Sea Coast.

CASSIUS E. GILLETTE, Capt., Corps of Engrs., U. S. A.

CHARLES H. MCKINSTRY, M. Am. Soc. C. E., Capt., Corps of Engrs., U. S. A.

NATURAL WATERWAYS.—*Subject No. 2:*

JAMES L. LUSK, M. Am. Soc. C. E., Maj., Corps of Engrs., U. S. A.

K. E. HILGARD, M. Am. Soc. C. E., Zurich, Switzerland.

ARTIFICIAL WATERWAYS.—*Subject No. 3:*

W. L. SIBERT, M. Am. Soc. C. E., Capt., Corps of Engrs., U. S. A.

W. H. HUNTER, M. Inst. C. E., Chief Engr., Manchester Ship Canal, England.

LIGHTHOUSES AND OTHER AIDS TO NAVIGATION.—*Subject No. 4:*

The United States Lighthouse Board.

THOMAS MATTHEWS, M. Inst. C. E., Chief Engr., Trinity House, London, England.

TRAFFIC ON IMPROVED WATERWAYS, ETC.—*Subject No. 5:*

EDWARD P. NORTH, M. Am. Soc. C. E., New York City.

PURIFICATION OF WATER.—*Subject No. 6:*

a. For Domestic Use.

ALLEN HAZEN, M. Am. Soc. C. E., New York City.

b. For the Production of Steam.

JAMES O. HANDY, Chief Chemist, Pittsburg Testing Laboratory, Pittsburg, Pa.

TURBINES AND WATER WHEELS.—*Subject No. 7:*

GARDNER S. WILLIAMS, M. Am. Soc. C. E., Ithaca, N. Y.

JOHN C. TEMPLE, M. Am. Soc. C. E., Philadelphia, Pa.

IRRIGATION.—*Subject No. 8:*

ELWOOD MEAD, M. Am. Soc. C. E., Chief, Irrigation Investigations, Washington, D. C.

Sir HANBURY BROWN, K. C. M. G., M. Inst. C. E., Late Chief Inspector of Irrigation, Lower Egypt.

RAILROAD TERMINALS.—*Subject No. 9:*

ELMER L. CORTHELL, M. Am. Soc. C. E., New York City.

UNDERGROUND RAILWAYS.—*Subject No. 10:*

William Barclay Parsons, M. Am. Soc. C. E., Chief Engr., Rapid Transit Comm., New York City.

Basil Mott, M. Inst. C. E., and David Hay, M. Inst. C. E., Central London and City and South London Railways, England.

LOCOMOTIVES AND OTHER ROLLING STOCK.—*Subject No. 11:*

William Forsyth, M. Am. Soc. M. E., Chicago, Ill.

G. J. Churchward, M. Inst. C. E., Chief Locomotive Supt., Great Western Ry., England.

LIVE LOADS FOR RAILROAD BRIDGES.—*Subject No. 12:*

Henry W. Hodge, M. Am. Soc. C. E., New York City.

THE SUBSTITUTION OF ELECTRICITY FOR STEAM AS A MOTIVE POWER.—*Subject No. 13:*

James G. White, M. Am. Soc. C. E., New York City.

Alexander Siemens, M. Inst. C. E., London, England.

SEWAGE DISPOSAL.—*Subject No. 14:*

George W. Fuller, Assoc. M. Am. Soc. C. E., New York City.

DISPOSAL OF MUNICIPAL REFUSE.—*Subject No. 15:*

Rudolph Hering, M. Am. Soc. C. E., New York City.

VENTILATION OF TUNNELS.—*Subject No. 16:*

Charles S. Churchill, M. Am. Soc. C. E., Chief Engr., Norfolk & Western R. R., Roanoke, Va.

Francis Fox, M. Inst. C. E., London, England.

HIGHWAY CONSTRUCTION.—*Subject No. 17:*

James Owen, M. Am. Soc. C. E., Newark, N. J.

William E. McClintock, M. Am. Soc. C. E., Chairman, Massachusetts Highway Comm., Boston, Mass.

CONCRETE AND CONCRETE-STEEL.—*Subject No. 18:*

Edwin Thacher, M. Am. Soc. C. E., New York City.

John S. Sewell, Capt., Corps of Engrs., U. S. A.

DEEP FOUNDATIONS.—*Subject No. 19:*

John F. O'Rourke, M. Am. Soc. C. E., New York City.

THE MANUFACTURE OF STEEL.—*Subject No. 20:*

William Metcalf, Past-Pres., Am. Soc. C. E., Pittsburg, Pa.

TESTS OF MATERIALS OF CONSTRUCTION.—*Subject No. 21:*

Steel.

William R. Webster, M. Am. Soc. C. E., Philadelphia, Pa.

Timber.

Gaetano Lanza, M. Am. Soc. M. E., Boston, Mass.

Cement.

William A. Aiken, M. Am. Soc. C. E., Pittsburg, Pa.

PASSENGER ELEVATORS.—*Subject No. 22:*

Thomas E. Brown, M. Am. Soc. C. E., New York City.

PUMPING MACHINERY.—*Subject No. 23:*

Irving H. Reynolds, M. Am. Soc. M. E., Youngstown, Ohio.

William Mayo Venable, Assoc. M. Am. Soc. C. E., New Orleans, La.

DREDGES: THEIR CONSTRUCTION AND PERFORMANCE.—*Subject No. 24:*

A. W. Robinson, M. Am. Soc. C. E., Montreal, Canada.
F. B. Maltby, M. Am. Soc. C. E., Memphis, Tenn.
J. C. Sanford, Maj., Corps of Engrs., U. S. A.

STEAM TURBINES.—*Subject No. 25:*

Francis Hodgkinson, M. Am. Soc. M. E., Pittsburg, Pa.

ELECTRICAL POWER—GENERATING STATIONS AND TRANSMISSION.—*Subject No. 26:*

L. B. Stillwell, M. Am. Soc. C. E., New York City.

NAVAL ARCHITECTURE.—*Subject No. 27:*

W. L. Capps, Rear Admiral, Chief Constructor, U. S. N.
Sir William H. White, K. C. B., F. R. S., President, Inst. C. E., late Director of Naval Construction, England.

MARINE ENGINEERING.—*Subject No. 28:*

W. F. Durand, M. Am. Soc. M. E., Ithaca, N. Y.

DRY DOCKS.—*Subject No. 29:*

M. T. Endicott, M. Am. Soc. C. E., Rear Admiral, Chief of Bureau of Yards and Docks, U. S. N.
Cuthbert A. Brereton, M. Inst. C. E., England.

ORDNANCE.—*Subject No. 30:*

Thales L. Ames, Capt., Ordnance Dept., U. S. A.
H. C. L. Holden, Lieut.-Col., R. A., F. R. S., Supt. of Royal Gun Factory, Woolwich, England.

FORTIFICATIONS.—*Subject No. 31:*

S. W. Roessler, Maj., Corps of Engrs., U. S. A.
George W. Goethals, Maj., Corps of Engrs., U. S. A.

MINING ENGINEERING.—*Subject No. 32:*

E. G. Spilsbury, M. Am. Soc. C. E., Trenton, N. J.

ENGINEERING EDUCATION.—*Subject No. 33:*

Robert Fletcher, Assoc. Am. Soc. C. E., Prof. of Civil Engineering, Dartmouth Coll., Hanover, N. H.
Calvin M. Woodward, Dean of Eng. School, Washington Univ., St. Louis, Mo.
W. Cawthorne Unwin, F. R. S., M. Inst. C. E., Cooper's Hill College and City and Guilds Technical College, London, England.

SURVEYING.—*Subject No. 35:*

HENRY M. WILSON, M. Am. Soc. C. E., Geographer, U. S. Geological Survey, Washington, D. C.
The United States Coast and Geodetic Survey.

WHARVES AND PIERS.—*Subject No. 37:*

JOHN A. BENSEL, M. Am. Soc. C. E., Engr. in Chief, Dept. of Docks and Ferries, New York City.

THE MANUFACTURE OF CEMENT.—*Subject No. 38:*

ROBERT W. LESLEY, Assoc. Am. Soc. C. E., Philadelphia, Pa.

PRIVILEGES OF LOCAL SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

The **Boston Society of Civil Engineers** will welcome any member of the American Society of Civil Engineers at its library and reading room, 715 Tremont Temple, Boston, which is open on week days from 9 A. M. to 5 P. M. Members will also be welcome at the meetings, which are held in the same building on the evenings of the fourth Wednesday in January, and the third Wednesdays of other months, except July and August.

The rooms of the **St. Louis Engineers' Club**, in the business center of St. Louis, will be kept open during the World's Fair season, May 1st to December 1st, 1904, and visiting engineers are cordially invited to use them for mail, telephone service, information, etc.

The courtesies of the **Engineers' Society of Western Pennsylvania** have been extended to members of the American Society of Civil Engineers. The rooms of the Society, 410 Penn Ave., Pittsburg, Pa., are open at all times, and meetings are held as follows, except during July and August: REGULAR SECTION, Third Tuesdays; CHEMICAL SECTION, Thursdays following third Tuesdays; MECHANICAL SECTION, first Tuesdays; STRUCTURAL SECTION, Fourth Tuesdays.

REPORT OF A COMMITTEE TO CO-OPERATE IN STANDARDIZING ABBREVIATIONS, SYMBOLS, PUNCTUATION, ETC., IN TECHNICAL PAPERS.

This Committee is the result of a desire of the authorities i charge of the publications of the four national engineering societie to co-operate in this matter.

The members of the Committee are the following:

CHARLES WARREN HUNT, Secretary, American Society of Civi Engineers; D. S. JACOBUS, Vice-President, American Society o Mechanical Engineers; JOSEPH STRUTHERS, Assistant Editor, America Institute of Mining Engineers; CARY T. HUTCHINSON, Chairman, Th Editing Committee, American Institute of Electrical Engineers.

This Committee has held several meetings; it seemed advisable at the outset, to limit its discussions closely to the general subjec of abbreviations. Further, it seemed best to formulate a few genera rules to be followed in making abbreviations, rather than to compil a list of forms to be recommended.

The Committee decided to limit the subject more narrowly b considering only abbreviations to be used in the text, or genera reading matter, and not those to be used in special matter, such a columns, box-headings, plates, figures, etc. The rules that follo are intended to apply to the text, and not primarily to such specia matter. This Committee is of the opinion that it is impracticable t make general rules applicable to special matter; it believes that th rules herein stated should be followed as far as possible even i special matter, realizing, however, that clearness is of the firs importance, and that all rules must be secondary to that consideratio

Referring, then, to abbreviations in the text or general readin matter, the Committee recommends the observance of the followi rules:

1.—Use abbreviations only after nouns denoting a definite qua tity. Example: "The power plant has a capacity of 10 h. p.," n "10 horse power;" but, "The capacity of the plant, in horse powe is ten."

2.—Do not abbreviate abstract or descriptive words. Exampl "Horizontal return tubular boilers," not "h. r. t. boilers."

3.—Use lower-case characters for abbreviations. An exception to this rule may be made in the case of words spelled normally with a capital. Example: "B. t. u." and not "b. t. u.," nor "B. T. U." (British thermal unit). "U. S. gal." (United States gallon). "B. & S. gauge" (Brown and Sharpe gauge).

4.—Use a period after each abbreviation. In a compound abbreviation, do not use a space after the period. Example: "i.h.p.," and not "i. h. p." (indicated horse power).

5.—Use a hyphen to connect abbreviations in cases where the words would take a hyphen if written out in full. When a hyphen is used, omit the period immediately preceding the hyphen. Example: "3 kw-hr." and not "3 kw.-hr." (3 kilowatt-hours).

6.—Use all abbreviations in the singular. Example: "17 lb." and not "17 lbs." (17 pounds); "14 in.," and not "14 ins." (14 inches).

7.—Never use "p." for "per," but spell out the word. Example: "100 ft-lb. per ton" (100 foot-pounds per ton); "60 miles per hr." (60 miles per hour).

8.—Use decimals, as far as possible, in place of vulgar fractions. Example: "1.25 ft.," not "1¼ ft."

9.—In general, spell out an adjective qualifying the name of a unit. Example: "Boiler h.p." (boiler horse power). The exceptions to this rule are: "i.h.p." (indicated horse power), "e.h.p." (electric horse power), "b.h.p." (brake horse power), "e.m.f." (electromotive force), "m.m.f." (magnetomotive force).

10.—Use "Fig.," not "Figure." Example: "Fig. 3," and not "Figure 3."

11.—In all decimal numbers having no units, a cipher should be placed before the decimal point. Example: "0.32 lb.," not ".32 lb."

12.—In the notation of large numbers, use "en" spaces instead of commas. Example: "1 520 125," not "1,520,125."

13.—Use the word "by" instead of "x" in giving dimensions. Example: "8 by 12 in.," not "8 x 12 in."

14.—Never use the characters (′) or (″) to indicate either feet and inches, or minutes and seconds as periods of time.

The following forms are given as illustrations of these rules, and are recommended to be used:

Name.	*Abbreviation.*	*Name.*	*Abbreviation.*
Inches	in.	Minutes	min.
Feet	ft.	Hours	hr.
Yards	yd.	Linear	lin.
Miles	spell out.	Square	sq.
Pounds	lb.	Cubic	cu.
Grains	gr.	Per	spell out.
Tons	spell out.	Fahrenheit	fahr.
Gallons	gal.	Centigrade	cent.
Metres	m.	Per cent.	% or per cent.
Millimetres	mm.	Volts	spell out.
Centimetres	cm.	Ohms	spell out.
Kilometres	km.	Watts	spell out.
Kilogrammes	kg.	Kilowatts	kw.
Grammes	g.	Kilowatt-hours	kw-hr.
Milligrammes	mg.	Watt-hours	watt-hr.
Seconds	sec.	Amperes	spell out.

Name.	*Abbreviation.*
Kilogramme-metres	kg-m.
Metre-kilogrammes	m-kg.
Brake horse power	b.h.p.
Electric horse power	e.h.p.
Indicated horse power	i.h.p.
British thermal units	B.t.u.
Gramme-calories	g-cal.
Kilogramme-calories	kg-cal.
Magnetomotive force	m.m.f.
Electromotive force	e.m.f.
Revolutions per minute	rev. per min.
Circular mils	cir. mils.
Miles per hour per second	miles per hr. per sec.
Candle-power	c-p.
Watts per candle-power	watts per c-p.
Mean effective pressure	spell out.
High-pressure cylinder	spell out.
Diameter	spell out.

The members of this Committee have agreed to recommend the authorities in charge of the publications of the four national engineering societies, to follow the rules given herein, in their respective publications, as far as possible.

New York, March 11th, 1904.

CHAS. WARREN HUNT,
D. S. JACOBUS,
JOS. STRUTHERS,
CARY T. HUTCHINSON.

The Publication Committee of this Society has adopted the recommendation of the above report, and the rules given in it will be followed in its publications, as far as possible.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ACCESSIONS TO THE LIBRARY.

From March 9th to April 12th, 1904.

DONATIONS.*

THE THEORY AND PRACTICE OF MODERN FRAMED STRUCTURES.

Designed for the Use of Schools, and for Engineers in Professional Practice. By J. B. Johnson, M. Inst. C. E., M. Am. Soc. C. E., M. Am. Soc. M. E., C. W. Bryan and F. E. Turneaure. Eighth Edition, Partly Rewritten. Cloth, 11 x 8 ins., 9 + 561 pp., illus. New York, John Wiley & Sons, 1904. $10.00.

The preface states that in this edition a considerable part of the work has been entirely rewritten and many changes made in other parts to bring them into harmony with the best modern practice. In the theoretical part of the book, the chapters on truss analysis for uniform loads have been entirely rewritten. Several changes have been made in the chapter on wheel-load methods; the chapter on conventional loads has been rewritten, and that on lateral trusses is nearly new. In the second part, the chapter on the design of plate girders has been largely rewritten, and that on the design of a pin-connected railway bridge entirely so. As a basis of the new designs used in these chapters, the American Bridge Company's specifications of 1900 have been adopted as being suited for this purpose. They are given in full in an appendix. The book is divided into two parts: Part I. Theory of Framed Structures; Part II. Structural Design. There are three appendices and an index of nine pages.

STEAM BOILERS, THEIR THEORY AND DESIGN.

By H. de B. Parsons. M. Am. Soc. C. E., M. Am. Soc. M. E. Cloth, 9 x 6 ins., 12 + 375 pp., illus. Longmans, Green, and Co., New York, 1903. $4.00. (Donated by the Author.)

This book comprises a series of lectures delivered to the senior class of the Rensselaer Polytechnic Institute, Troy, N. Y., rewritten and divided into chapters. The only originality claimed by the author for the work is the effort to cover such points as in practical office work may be found perplexing. The Contents are: Physical Properties; Combustion; Fuels; Furnace Temperature and Efficiency of Boiler; Boilers and Steam Generators; Chimney Draft; Materials; BoilerDetails; Boiler Fittings; Mechanical Stokers; Artificial Draft; Incrustation; Corrosion; General Wear and Tear, Explosions; Chimney Design: Smoke Prevention; Testing, Boiler Coverings, Care of Boilers; Superheated Steam. There is an index of six pages.

THE LAY-OUT OF CORLISS VALVE GEARS.

By Sanford A. Moss, M. Am. Soc. M. E. Reprinted from *The American Machinist*, with Revisions and Additions. Cloth, 6 x 4 ins., 108 pp., illus. New York, D. Van Nostrand Company, 1903. 50 cents.

This volume is an attempt to treat the Corliss valve gear from a theoretical point of view. An endeavor is made to treat the "single eccentric" motion from a rational standpoint. A discussion is given of the theoretical principles underlying the kinematic design or "lay-out" as it is commonly called. This is followed by directions for making a lay-out on the drawing-board. Reference is also made to the Corliss valve motion with double wrist-plate and long-range cut-off. For the sake of completeness a preliminary account is given of the usual mechanism of a Corliss valve gear. Beyond this description nothing is given concerning the detailed construction of the various parts, the kinematic features only, rather than the constructive features, being considered. The Chapter headings are: Description of the Corliss Valve Gear Mechanism; Operation of Corliss Valve Gears; Fundamental Influence of the Angle of Advance; Relative Motions of Eccentric, Wrist Plate and Valves; Theory of the Corliss Wrist Plate; Valve Displacement Curves; Selection of the Arbitrary Dimensions of a Corliss Gear; Laying out the Single Wrist Plate Corliss Gear on the Drawing-Board.

TOWERS AND TANKS FOR WATER-WORKS.

The Theory and Practice of Their Design and Construction. By J. N. Hazlehurst, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 10 + 324 pp., illus. New York, John Wiley & Sons, 1904. $2.50.

In this edition, eliminations have been made, and typographical and other errors have been corrected; the work throughout has been largely revised and rewritten, and

* Unless otherwise specified, books in this list have been donated by the publishers.

many new illustrations have been added. The new matter includes a record of standpipe failures, continuing from the time of Prof. Pence's monograph to the present; a chapter dealing with the stresses in a steel water-tower, originally presented in the *Technograph*, and revised and rewritten by its author for this work; also two chapters upon the subject of specifications for and the architectural and ornamental possibility of water-tower design. The Contents are: Introduction; Historical; The Chemical and Physical Properties of Structural Metal; Structural Metals; Stress or Strain, and Stability of Structure; Mechanical Principles; The Stresses in a Steel Water-Tower; Riveting; Designing; Foundations; Painting; Shop Practice and Erection; Specifications; Architecture and Ornamentation. There is an index of five pages.

ARCHITECTS' AND ENGINEERS' HAND-BOOK OF REINFORCED CONCRETE CONSTRUCTIONS.

Giving in Plain and Simple Language the Leading Principles and Applications of this Modern Construction. By L. J. Mensch. Paper, 7½ x 5 ins., 217 pp., illus. Chicago, Cement and Engineering News. $2.00.

The information in this hand-book is drawn largely from the writer's experience as designer, consulting engineer and contractor for reinforced concrete constructions. In the practice of his profession, in various parts of the country, the author has been brought into contact with architects, engineers and others interested in this method of construction. These clients have from time to time asked numerous questions relating to the essential features of reinforced concrete construction, especially as compared with other materials and forms of construction. These questions and the author's answers were uniformly reduced to writing and classified, and now form a portion of this handbook, together with other material bearing on the subject. The author has aimed to treat the subject in plain and simple language, free from higher mathematical calculations. There is an index of two pages.

RECHERCHES EXPERIMENTALES SUR LA CONSTITUTION DES MORTIERS HYDRAULIQUES.

Par H. Le Chatelier. Cloth, 10 x 6 ins., 4 + 199 pp., illus. Paris, Vve. Ch. Dunod, 1904. Broché, 6 francs; cartonné, 7 francs, 50.

The introduction states that the principal object of this work is the study of the chemical reactions produced in limes and hydraulic cements during their calcination and setting. The author has taken as a preliminary study the more simple analogous substances, lime and silicates of barytes, hoping that a knowledge of the elements of which these are composed will throw light on the theory of calcareous cements. The work is divided into three parts: Part I. Plâtre; Part II. Silicates de Baryte; Part III. Ciment et Chaux Hydrauliques.

THE ELECTROLYSIS OF WATER.

Processes and Applications. By Viktor Engelhardt. Authorized English Translation by Joseph W. Richards. Cloth, 9 x 6 ins., 10 + 140 pp., illus. Easton, Pa., Chemical Publishing Co., 1904. (Monographs on Applied Electrochemistry. Vol. I.)

In the collection of *Monographs of Applied Electrochemistry*, of which this is the first volume, it will be the object to set forth detailed and authentic reports in the field of applied electrochemistry. These monographs will be special reports, in which the entire historical development will be set forth, and a review of the most important patent literature made. A considerable proportion of the English-speaking electrochemists can read the German text, but a still larger proportion cannot, and that the latter class may have access to the thoughts and ideas of this monograph is the purpose of the translation. The Contents are: Historical Review; The Constants of the Electrolytic Decomposition of Water; Review of Processes—Processes and Apparatus for the Separate Production of Oxygen and Hydrogen; Processes and Apparatus for the Electrolysis of Water without Separation of the Gas, Processes for the Simple Evolution of Oxygen; Applications; Appendix. There is an index of two pages.

FACTS ABOUT PEAT, PEAT FUEL AND PEAT COKE.

How to Make It and How to Use It—What It Costs and What It Is Worth, with Brief Notes Concerning Its Use and Value for Numerous Other Purposes. By T. H. Leavitt. Cloth, 7½ x 5 ins., 115 pp. Boston, Lee and Shepard, 1904. $1.00 net.

A number of years ago the author operated works at Lexington, Massachusetts, for the manufacture of peat fuel, and for the perfecting of machinery for its production.

During that time he prepared a volume entitled "Facts About Peat," which is now ou of print, the plates having been destroyed by fire. The present volume, therefore under the same title, is prepared as a substitute for that, with a view to affording infor mation of a practical character to those proposing to manufacture or use such fue The chapter headings are: What is Peat? Where Peat is Found; How to Make Pea Fuel: Peat Coke; Intensity of Heat Generated by Peat Fuel; Peat Fuel for Domesti Purposes; Peat as a Fuel for Generating Steam; Peat in the Manufacture of Iron an Steel; Other Uses of Peat Fuel; Peat for Gunpowder and Fireworks; Gas from Peat Cost and Market Value of Peat Fuel; The Market for Peat Fuel; Chemical Products c Peat; Ashes of Peat; Conclusions; Antiseptic Properties of Peat; Peat as a Disinfectar and Deodorizing Agent; Other Uses for Peat; Peat as a Fertilizer; Peat Moss Litte Mixed Fuels; Caution and Encouragement; What Shall We Do About it? Appendix.

RIVER TRAINING AND CONTROL.

Being a Description of the Theory and Practice of the Modern Sys tem Entitled the Guide Bank System, Used in India for the Contro and Guidance of Great Alluvial Rivers. By Francis J. E. Spring, M Inst. C. E., M. Inst. Mech. E., M. Am. Soc. C. E. Cloth, 14 x 9 ins. various paging, 50 plates. Simla, Government Central Printin Office, 1903. (Donated by the Author.)

The scheme of the book is as follows: After a brief introductory chapter, whic attempts to give an idea of the importance of the subject, a comparison is made be tween the Mississippi and Indian rivers of the class chiefly dealt with. Chapters III IV and V deal with river action. Chapter VI shows how different are the sands of dif ferent rivers in their susceptibility to water transportation. Chapters VII to X inclusive, explain the principles, as the author understands them, underlying the du design of the class of works which give this book its title. Chapter XII deals with riparia towns, etc., of the narrowing of soft bedded rivers, by means of guide banks at th abutments of bridges or weirs. The next ten chapters are devoted to a history of th training works of certain selected bridges and weirs. In these chapters the author ha endeavored to show how the idea of the modern guide bank gradually grew out of a number of experiences, until it was formulated at last definitely. Chapters XXIII an XXV show how the author has designed the guide banks and depth of foundations fo the projected Lower Ganges bridge. Chapter XXIV is devoted to such evidence on th subject as seems likely to be useful to bridge designers. Chapter XXVI sums up the evi dence, and Chapter XXVII makes some suggestions. An appendix follows giving genera information and a list of some literature on the subject.

MAVER'S WIRELESS TELEGRAPHY.

Theory and Practice. By William Maver, Jr., M. Am. Inst. E. E Cloth, 9 x 6 ins., 6 + 199 pp., illus. New York, Maver Publishin Company, 1904. $2.00.

The preface states that in this work each subject has been treated both from a theo retical and a practical standpoint, in a language as free as possible from formulæ, an the whole has been written in a manner designed to be clear to the general reader. Th descriptions of systems and apparatus, with a few exceptions, are limited to those i actual operation. It is believed, however, that the book will be found to contain muc more than a mere account of the wireless systems at present in use. In fact, the ai has been to give a comprehensive statement of all that appertains to the art at thi time, in the hope of supplying herein a complete practical handbook of wireless teleg raphy. The contents are: Induction Telegraphy; Electric or Hertzian-Wave Telegraphy Early Experiments in Electric-Wave Telegraphy; Theory of Electric-Wave Propagation Syntonic Wireless Telegraphy; Marconi Wireless Telegraph Systems; Lodge an Lodge-Muirhead Wireless Telegraph Systems; The Slaby-Arco and Braun Wireles Telegraph Systems; The Branly-Popp, Guarini, and Ducretet-Popoff Wireless Tele graph Systems; The De Forest Wireless Telegraph System; The Fessenden, Stone Shoemaker, and Musso Systems; Signaling by Ultra Violet Rays; Wireless Telephony Detectors, Interruptors, Transformers, etc.; Practical Applications of Wireless Teleg raphy; Appendix. There is an index of six pages.

THE METRIC FALLACY.

By Frederick A. Halsey; and, The Metric Failure in the Textil Industry. By Samuel S. Dale. Cloth, 9 x 6 ins., 231 pp., illus New York, D. Van Nostrand Company, 1904. $1.00.

This book is the outgrowth of a paper presented to the American Society of Mechan ical Engineers at its December meeting, 1902, and the discussion which followed. Th points raised in the discussion have been rewritten and placed in their appropriat places. The list of countries in which it was shown in the paper that old units continue in use has been about quadrupled, while new chapters have been added on "The

Reasons for the Failure of Compulsory Laws," "Scientific and Industrial Measurements," "Scientific and Industrial Difficulties," "The Complications Due to a Mixture of Units," "The Inaccuracy of the Meter," "The Abandoned Portions of the Metric System" and "The Object of the Bill." Part II, on The Metric Failure in the Textile Industry, has also been entirely rewritten. The table of Continental systems of numbering spun yarn has been compiled from the latest French, German and Spanish authorities; Care has been taken to eliminate all systems not in actual use. There is an appendix entitled Action of Various Associations on the Metric System Bill which was reported favorably to the Fifty-Seventh Congress.

Gifts have also been received from the following:

Am. Electro-Therapeutic Assoc. 1 pam.
Am. Inst. Min. Engrs. 1 pam.
Am. Soc. Mech. Engrs. 1 vol.
Am. St. Ry. Assoc. 21 vol.
Assoc. Amicale des Anciens Élèves de l'École Centrale des Arts et Manufactures. 8 nos.
Assoc. of Executive Health Officers of Ontario. 1 pam.
Bettinger, Albert. 1 pam.
Binghamton, N. Y.—Water Commrs. 1 pam.
Bouscaren, G. 1 bound vol.
Brookline, Mass.—Water Board. 1 pam.
Brooklyn Engrs.' Club. 1 bound vol.
Cal.—State Board of Health. 5 bound vol., 3 pam.
Cal.—State Min. Bureau. 1 vol., 6 pam.
Canada—Geol. Surv. 1 bound vol.
Canadian Min. Inst. 1 vol., 2 pam.
Central Ry. Club. 1 pam., 6 nos.
Chicago, St. Paul, Minneapolis & Omaha Ry. Co. 1 pam.
Churruco, Evaristo de. 23 pam., 1 bound vol.
Cleveland, Ohio—Mayor. 3 pam.
Cumberland Valley R. R. Co. 1 pam.
Delaware & Hudson Co. 1 pam.
Eddy, H. P. 1 pam.
Engrs. Soc of Western New York. 1 pam.
Exploration Co. Ltd. 3 pam.
Glasgow & South-Western Ry. Co. 1 pam.
Grand Rapids & Indiana Ry. Co. 1 pam.
Great Britain—Patent Office. 5 vol., 7 pam.
Green Bay & Western R. R. Co. 1 pam.
Hartford Steam Boiler Inspection & Insurance Co. 3 nos.
Harvard Univ. 1 vol.
Hilgard, K. E. 1 pam.
Hodgdon, Frank W. 1 bound vol.
Holyoke, Mass.—Board of Water Commr. 1 pam.
Hutton, N. H. 1 pam.
Ill.—Agri. Exper. Station. 2 pam.
Ind.—State Board of Health. 10 bound vol.
Kirkpatrick, Walter G. 1 pam.
Lansing, E. T. E. 1 pam.
Lehigh Univ. 1 vol.
Leominster, Mass.—Water Board. 1 pam.
Levering, J. H. 3 pam.
Lewis, N. P. 1 bound vol.
McKeesport, Pa.—Board of Water and Lighting Commrs. 1 pam.
Mass.—Board of Gas and Electric Light Commrs. 1 bound vol., 14 vol.
Mass.—Board of Metropolitan Park Commrs. 1 bound vol.
Mass.—Highway Comm. 1 bound vol.
Mass. Inst. of Technology. 2 vol.
Merchants' Exchange of St. Louis, Mo. 1 vol.
Met. West Side Elevated Ry. Co. 1 pam.
Minn.—R. R. & Warehouse Comm. 1 vol.
Minn.—State Board of Health. 1 pam.
Missouri Pacific Ry. Co. 1 vol.
National Arts Club. 1 pam.
National Assoc. of German-Am. Technologists. 3 vol., 9 nos.
N. J. Sanitary Assoc. 1 pam.
N. Y. R. R. Commrs. 2 bound vol.
N. Y.—State Library. 1 pam., 1 bound vol.
North, Edward P. 1 pam.
Northampton, Mass.—Water Commrs. 1 pam.
Ohio Soc. of Surv. and Civ. Engrs. 3 vol.
Ontario—Bureau of Mines. 3 vol., 1 bound vol.
Ontario—Provincial Board of Health. 3 vol.
Opdyke, Howard. 18 pam.
Orr, Alexander. 1 pam.
Philadelphia Co. 5 pam.
Platt, T. C. 1 bound vol.
Rafter, Geo. W. 2 bound vol.
Ry. Signal Assoc. 3 vol.
Revista de Construcciones y Agrimensura. 1 pam.
R. I.—State Board of Health. 1 bound vol.
Roebling Construction Co. 1 pam.
Slocum, C. M. 1 pam.
Smithsonian Inst. 1 bound vol.
Société Belge des Ingénieurs. 8 pam.
Soc. of Naval Architects and Marine Engrs. 1 bound vol.
Springfield, Mass.—Board of Water Commrs. 1 pam.
Technology Quarterly. 2 vol.
Texas Univ.—Mineral Survey. 2 pam.
Thomson, Geo. H. 1 pam.
U. S. Bureau of Chemistry. 1 pam.
U. S. Bureau of Equipment. 5 vol.
U. S. Bureau of Navigation. 14 pam., 1 1 bound vol.
U. S. Bueau of Pub. Health & Marine Hospital Service. 6 bound vol.
U. S. Bureau of Statistics. 2 vol., 1 bound vol.
U. S. Coast & Geodetic Surv. 1 bound vol.
U. S. Commr. of Navigation. 6 bouud vol.
U. S. Corps of Engrs. 5 bound vol., 35 specif., 1 vol.
U. S. Geol. Surv. 2 bound vol., 6 pam.
U. S. Interstate Commerce Comm. 1 bound vol., 3 pam.
U. S. Naval Observatory. 1 vol.
U. S. Supt. of Documents. 1 bound vol., 6 nos.
Univ. of Pa. 1 pam.
Wellington, New Zealand—Harbor Board. 1 pam.
Yazoo-Miss. Delta Levee District—Chf. Engr. 3 pam.

BY PURCHASE.

Electric Transmission of Energy and Its Transformation, Sub- division, and Distribution. A Practical Handbook. By Gisbert Kapp, M. Inst. C. E., M. Inst. E. E. Fourth Edition, thoroughly Revised. New York, D. Van Nostrand Company.

Der Drehstrommotor. Ein Handbuch für Studium und Praxis. Von Julius Heubach. Berlin, Julius Springer, 1904.

Messungen an Elektrischen Maschinen. Apparate, Instrumente Methoden, Schaltungen. Von Rudolf Krause. Berlin, Julius Springer, 1903.

Der Elektrische Lichtbogen bei Gleichstrom und Wechselstrom und Seine Anwendungen. Von Berthold Monasch. Berlin, Julius Springer, 1904.

Naval Architecture. By Cecil H. Peabody. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

Submarine Navigation, Past and Present. By Alan H. Burgoyne. 2 vol. New York, E. P. Dutton & Co.; London, Grant Richards, 1903.

Indicator Practice and Steam Engine Economy. With Plain Directions for Attaching the Indicator, Taking Diagrams, Computing the Horsepower, Drawing the Theoretical Curve, Calculating Steam Consumption, Determining Economy, Locating Derangement of Valves, and Making All Desired Deductions; also Tables Required in Making the Necessary Computations, and an Outline of Current Practice in Testing Steam-Engines and Boilers. By Frank Hemenway. Sixth Edition. New York, John Wiley & Sons; London, Chapman & Hall, Ltd., 1903.

Machine Design. Part I. Kinematics of Machinery. By Forrest R. Jones. Third Edition, Revised. New York, John Wiley & Sons, 1903.

Who's Who, 1904. An Annual Biographical Dictionary. London, Adam and Charles Black; New York, The Macmillan Company, 1904.

How to Lay Out a Garden: Intended as a General Guide in Choosing, Forming, or Improving an Estate, with Reference to Both Design and Execution. By Edward Kemp. Third Edition. New York, John Wiley & Sons, 1901.

The Civil Engineer's Pocket-Book. By John C. Trautwine. Revised by John C. Trautwine, Jr., and John C. Trautwine, 3d. Eighteenth Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

Cram's Standard American Railway System Atlas of the World, Showing all the Railway Systems in Colors, Accompanied by a Complete and Simple Index of the United States Showing the True Location of All Railroads, Towns, Villages and Post-Offices. New York and Chicago, George F. Cram, 1904.

The Elements of Mining and Quarrying. By Sir C. Le Neve Foster. London, Charles Griffin and Company, Limited; New York, The Engineering and Mining Journal, 1903.

Ore Deposits of the United States and Canada. By James Furman Kemp. Fifth Edition, Entirely Rewritten and Enlarged. The Engineering and Mining Journal, New York, London, 1903.

The Non-Metallic Minerals. Their Occurrence and Use. By George P. Merrill. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

The Prospector's Field-Book and Guide in the Search for and the Easy Determination of Ores and Other Useful Minerals. By H. S. Osborn. Sixth Edition, thoroughly Revised and Enlarged. Philadelphia, Henry Carey Baird & Co., 1903.

Disinfection and the Preservation of Food, together with an Ac-count of the Chemical Substances Used as Antiseptics and Preservatives. By Samuel Rideal. London, The Sanitary Publishing Co., Ltd.; New York, John Wiley and Sons, 1903.

Domestic Sanitary Drainage and Plumbing. Lectures on Practical Sanitation Delivered to Plumbers, Engineers, and Others in the Central Technical Institution, South Kensington, London, Under the Auspices of the City and Guilds of London Institute for the Advancement of Technical Education. By William R. Maguire. Third Edition, Revised and Brought up to Date. London, Kegan Paul, Trench, Trübner & Co., Ltd., 1901.

Elements of Bacteriology, with Special Reference to Sanitary Water Analysis. By Samuel Cate Prescott and Charles-Edward Amory Winslow. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

Rustless Coatings: Corrosion and Electrolysis of Iron and Steel. By M. P. Wood, M. Am. Soc. M. E. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1904.

Handbuch der Baukunde. Eine systematische und vollständige Zusammenstellung der Resultate der Bauwissenschaften mit den zugehörigen Hilfswissenschaften. Veranstaltet von den Herausgebern der Deutschen Bauzeitung und des Deutschen Baukalenders. Vol. III, Pts. 1–4. Berlin, Ernst Toeche, 1890–95.

SUMMARY OF ACCESSIONS.

March 9th to April 12th, 1904.

Donations (including 25 duplicates and 23 numbers completing volumes of periodicals)	361
By purchase	24
Total	385

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
CASE, JAMES FRANCIS. City Engr., Manila, Philippine Islands.		Jan. 6, 1904
CHAMBERS, RALPH HAMILTON. (Chambers & Hone), 60 New St., New York City..	Assoc. M. M.	Dec. 1, 1897 April 5, 1904
COX, LEONARD MARTIN. Civ. Engr., U. S. N., Superv. Engr., Steel Floating Dock for Cavite, P. I., Sparrows Point, Md.	Assoc. M. M.	Oct. 4, 1899 Jan. 5, 1904
CURRY, CHARLES WHITE. Tustin, Orange Co., Cal		Mar. 2, 1904
FOWLER, THOMAS WALKER. Univ. of Melbourne, Melbourne, Victoria, Australia		Dec. 2, 1903
GREGORY, LUTHER ELWOOD. Civ. Engr., U. S. N., Navy Yard, Portsmouth, N. H		April 6, 1904
HORTON, GEORGE TERRY. Engr. and Mgr., Chicago Bridge & Iron Works, 105th and Throop Sts., Chicago, Ill		April 6, 1904
MATHEWSON, ISAAC. Santa Fé, Distrito de Alarcon, Guerrero, Mexico	Assoc. M. M.	Mar. 7, 1894 Mar. 1, 1904
MOBERLY, FRANK. Victoria, B. C., Canada		Oct. 7, 1903
NETHERCUT, EDGAR S. 427 Monadnock Blk., Chicago, Ill		April 6, 1904
POTTER, WILLIAM BANCROFT. Chf. Engr., Ry. Dept., Gen. Elec. Co., Schenectady, N. Y		Mar. 2, 1904
QUINN, RICHARD. Fort St. Philip, La		Mar. 2, 1904
STORROW, SAMUEL. Civ. and Min. Engr., 401 Douglas Bldg., Los Angeles, Cal	Jun. Assoc. M. M.	Sept. 10, 1891 Oct. 2, 1895 Mar. 1, 1904
WISE, COLIN REED. Civ. and San. Engr., 301 Gregory Ave., Passaic, N. J		April 6, 1904

ASSOCIATE MEMBERS.

ADAMS, ARTHUR, 132 Oneida St., Utica, N. Y	Jun. Assoc. M.	Oct. 1, 1901 April 6, 1904
BRINSMADE, DANIEL EDWARDS. Box 545, Derby, Conn		April 6, 1904
BUZZELL, JOSIAH WILLIAM. Gen. Mgr. and Chf. Engr. for Frank B. Gilbreth, 176 Federal St., Boston, Mass		April 6, 1904
CAMERON, JOHN BOBBS. Div. Engr., B. & O. R. R., New Castle, Pa	Jun. Assoc. M.	Oct. 2, 1900 Feb. 3, 1904
DUNCAN, LINDSAY. Prof. of Civ. Eng., Univ. of Colorado, Boulder, Colo		Feb. 3, 1904
ELY, JOHN STANTON. 1107 Tioga St., Philadelphia, Pa		Mar. 2, 1904
FALES, FRANK LEWIS. Eng. Dept., Commrs. of Water-Works, City Hall, Cincinnati, Ohio		April 6, 1904
GOVE, WILLIAM GRANVILLE. Asst. Mech. Engr., Brooklyn Heights R. R. Co., 168 Montague St., Brooklyn, N. Y..		Feb. 3, 1904
GREEN, FRED MAY. 187 Madison Ave., New York City		April 6, 1904
LEE, ENGBERT A. Cons. Engr. (Bonnevie & Lee), 17 Jacobson Bldg., Denver, Colo		Oct. 7, 1903

		Date of Membership.
LEWIS, LUTHER HAMMOND. 360 West 55th St., New York City.		April 6, 1904
LIPSEY, THOMAS EUGENE LEARD. Box 585, Beaver, Pa.		April 6, 1904
LOGAN, WILLIAM SEELEY. 39 Midland Ave., Arlington, N. J.		April 6, 1904
MORISON, WILLIAM SMITH. P. O. Box 47, Penns Grove, N. J.		April 6, 1904
NICHOLS, CLARENCE HICKS. Care, Sanderson & Porter, 52 William St., New York City		April 6, 1904
RAYNOR, CLARENCE WEBSTER. First Asst. Engr., The Midland Bridge Co., Kansas City, Mo.	Jun.	Feb. 4, 1902
	Assoc. M.	April 6, 1904
SMITH, LLOYD BOWN. Care, Missouri Val. Bridge & Iron Works, Leavenworth, Kans		April 6, 1904
SPEAR, WALTER EVANS. Care, Am. Express Co., 11 Rue Scribe (Opera), Paris, France		Feb. 3, 1904
WOOD, WINTHROP BARRETT. Engr., Wanskuck Co., Wanskuck Mills, Providence, R. I		April 6, 1904

JUNIORS.

BIRKS, ARTHUR HENRY. P. O. Box 682, Phœnixville, Pa.	April 5, 1904
BRINKLEY, MILO HAMILTON. Care, A. P. Davis, U. S. G. S., Phœnix, Ariz	Mar. 1, 1904
BURBAGE, JOHN OTIS. 2325 Fillmore St., San Francisco, Cal.	Mar. 1, 1904
KLEINSCHMIDT, HENRY SCHWING. P. O. Box S, Salt Lake City, Utah	Mar. 1, 1904
ROBINSON, GEORGE LOOMIS. 32 Broadway, New York City	April 5, 1904
SACKETT, ARTHUR JOHNSON. U. S. Engr. Office, Jacksonville, Fla	Mar. 1, 1904
SAUCEDO, VICENTE. Care, R. Johnson, M. I. R. R., Durango, Dgo., Mexico	Oct. 6, 1903
SUTTON, CHARLES WOOD. Lima, Peru	Dec. 1, 1903
YATES, WILLIAM HENRY. Asst. in Civ. Eng., Columbia Univ., 309 West 128th St., New York City	Feb. 2, 1904

CHANGES OF ADDRESS.

MEMBERS.

ADAMS, ARTHUR LINCOLN	Hydr. Engr., Hayward's Bldg., San Francisco, Cal.
ALBERTSON CHARLES	Bangor, Pa.
BACON, JAMES HAYWARD	Northern Hotel, Port Arthur, Ont., Canada.
BAKER, WILLIAM EDGAR	27 William St., New York City.
BALL, CHARLES BACKUS	Chf. San. Insp., Dept. of Health, Room 113, City Hall, Chicago, Ill.
BEARDSLEY, JAMES WALLACE	Cons. Engr. to the Comm., Manila, Philippine Islands.
BIXBY, WILLIAM HERBERT	Maj., Corps of Engrs., U. S. A., 246 Belvidere Ave., Detroit, Mich.
DUNHAM, LEWIS AUGUSTUS	Cons. Engr., Am. Zinc Extraction Co., 318 Dwight Bldg., Kansas City, Mo.

DUNN, DANIEL BURKE .... Div. Engr., Constr , Atlanta & Birmingham Air Line Ry., 1007 English-American Bldg., Atlanta, Ga.

FITCH, CHARLES LINCOLN .... Cons. Engr., 253 Throop Ave., Brooklyn, N. Y.

FRITCH, LOUIS CHARLTON .... Care, Gen. Supt., Transportation, Ill. Cent. R. R., Chicago, Ill.

GIBBS, CHARLES WINGATE .... Civ. and Min. Engr., Kearney, Nebr.

GOING, ALVAH SEYMOUR .... Asst. Engr., Grand Trunk Pacific Ry., Victoria, B. C., Canada.

HARLOW, JAMES HAYWARD .... Chf. Engr., Susquehanna Elec. Power Co., 2 E. Pleasant St., Baltimore, Md.

HAZARD, SCHUYLER .... Roadway Engr., Southern Ry., Woodward Bldg., Birmingham, Ala.

HOLBROOK, ELLIOT .... La Jolla, San Diego Co., Cal.

HOWELL, FRANKLIN DAVINPORT, JR... P. O. Box 308, Monrovia, Cal.

KIMBALL, FRANK CLIFTON .... 14 Beacon St., Boston, Mass.

LEWIS, FREDERICK HUMPHREVILLE.... Mgr., Virginia Portland Cement Co., Fordwick, Va.

LOCKWOOD, JAMES BUTTON CLYDE..... Cons. Engr., 323 Globe Bldg., Seattle, Wash.

LOFLAND, HENRY FIDDEMAN .... Div. Erecting Mgr., Am. Bridge Co. of N. Y., N. W. Cor. 15th and Chestnut Sts., Philadelphia, Pa.

LOWETH, CHARLES FREDERICK .... Engr. and Supt., Bridges and Bldgs., C., M. & St. P. Ry., 1232 Railway Exchange, Chicago, Ill.

McNICOL, JOHN ALEXANDER .... 11 Mercaderes, Havana, Cuba.

MAXSON, FRANK OSCAR .... Civ. Engr., U. S. N., Navy Yard, League Island, Pa.

MITCHELL, SAMUEL PHILLIPS .... Chf. Engr., Am. Bridge Co. of N. Y., Room 1525, Frick Bldg., Pittsburg, Pa.

PRICHARD, HENRY SEWALL .... Am. Bridge Co., Frick Bldg., Pittsburg, Pa.

SCHULTZ, ALBERT LOUIS .... Cons. Engr., Pittsburg Eng. Co., 1210 Keystone Bldg., Pittsburg, Pa.

SHMELEFF, THEODOR SEMENOVITCH.... Sotschi, Caucasus, Russia.

SMOOT, EDGAR KENNETH .... Concessionario de las obras del Puerto de Manzanillo, Mexico, 79 Paseo de la Reforma, City of Mexico, Mexico.

STUART, FRANCIS LEE .... Engr. of Surveys, B. & O. R. R., Mount Royal Station, Baltimore, Md.

TAYLOR, WILLIAM DANA .... Prof., Railway Eng., Univ. of Wisconsin, 430 Sterling Pl., Madison, Wis.

WEGMANN, EDWARD .... Care, New York Aqueduct Comm., Stewart Bldg., New York City.

WILSON, CHARLES BEATTY .... Roadmaster, Atlanta Div., N., C. & St. L. Ry., Box 285, Marietta, Ga.

ASSOCIATE MEMBERS.

BAUM, GEORGE .... Representative, Westinghouse, Church, Kerr & Co., Engrs., 1327 Empire Bldg., Atlanta, Ga.

BRYSON, THOMAS BINES..............Care, O'Rourke Eng. Constr. Co., Nassau and Cedar Sts., New York City.

BURNS, JUSTIN......................35 Gotham St., Watertown, N. Y.

DAVIS, FRED RUFUS..................Res. Engr., Elder's Ridge Branch, Buffalo, Rochester & Pitts. Ry. Co., Goffstown, N. H.

GRAY, EDWARD, Jr...................Tidewater Ry. Office, Roanoke, Va.

GRISWOLD, RAY ELLIOTT..............Supt., The Barber Asphalt Paving Co.'s Refinery, Madison, Ill.

HAYCROFT, JAMES ISAAC..............Fontenoy, The Grove, Queen St., Woollahra, New South Wales, Australia.

ILSLEY, ARTHUR BENJAMIN............Asst. Engr., Southern Ry., Washington, D. C.

JAUDON, HENRY SCUDDER.............Elberton, Ga.

LOCKWOOD, WILLARD DATUS..........17 Grove Pl., Rochester, N. Y.

ROCKENBACH, SAMUEL DICKERSON.....Capt., 12th U. S. Cavalry, Manila, Philippine Islands.

ROMMEL, GEORGE, Jr.................Engr. in Chg. of Sewers, Wilmington, Del.

ROUNDEY, EUGENE PERONNEAU........229 Linwood St., Cleveland, Ohio.

SHIMA, TAKEJIRO....................Schlüterstrasse 12, Charlottenburg, Berlin, Germany.

SWEITZER, NELSON BOWMAN...........Surveying Div., Gen. Land Office, Washington, D. C.

THEBAN, JOHN GERARD...............Engr. in Chg. of Dept. of Bridges, Borough of the Bronx, 700 Southern Boulevard, New York City.

VERVEER, EMANUEL LOUIS............Contr. Engr., Milliken Bros., 71 West 105th St., New York City.

WIGGIN, THOMAS HOLLIS.............Div. Engr., Bureau of Filtration, 6350 Marchand St., Pittsburg, Pa.

WRIGHT, MOSES HANNIBAL............Asst. Engr., A., K. & N. Ry. Co., 512 Prudential Bldg., Atlanta, Ga.

JUNIORS.

BELZNER, THEODORE..................Insp., Steel Constr., East Side Viaduct, Rapid Transit R. R. Comm., 231 West 125th St. (Res., 584 Lenox Ave.), New York City.

CLASS, CHARLES FRANK ....Asst. Engr., Am. Coke & Gas Constr. Co., Camden, N. J. (Res., 1332 E. Rittenhouse St., Germantown, Philadelphia, Pa.)

HARSHBARGER, ELMER DWIGHT........Ronceverte, W. Va.

HOWE, CHARLES EDWARD.............Treas., Wabash Mfg Co., Wabash, Ind.
ILLICH, JOSEPH THOMAS.............Care, C. H. Ledlie, 920 Rialto Bldg., St. Louis, Mo.
MELICK, NEAL ALBERT...............Room 521, Grand Central Station, New York City.
MURRAY, RAY........................Asst. to Chf. Engr., Am. Bridge Co. of N. Y., Ambridge, Pa.
PISTOR, GEORGE EMIL JOHN...........Designing and Contr. Engr., Hay Foundry & Iron Works, 140 West Fayette St., Baltimore, Md.
SAWYER, WILBUR CYRUS...............Care, U. S. Geological Survey, Pendleton, Ore.
WEAVER, FRANK MAURICE............2037 Master St., Philadelphia, Pa.

DEATHS.

MARINDIN, HENRY LOUIS............ Elected Member, May 7th, 1884; died March 25th, 1904.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(March 8th to April 13th, 1904.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal, London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.

LIST OF ARTICLES.

Bridge.

The Graphical Calculation of Flange Stresses in Girders and Trusses.* Oscar San (4) Feb.
Opening Bridge over Barking Creek * (12) Mar. 4.
Cantilever Bridge over the East River.* (11) Mar. 4.
Counterbalanced Draw Span on the Chicago, Milwaukee & St. Paul.* (15) Mar. 11.
Bridge Work on the Wabash Extension.* (18) Mar. 12.
Some Concrete Arch Bridge Construction on the Illinois Central R. R.* (18) Mar. 12.
Renewal of Bridge at Croton Lake, N. Y. C. & H. R. R. R.* (18) Mar. 12.
Concrete Arch Bridge at Herkimer, N. Y.* (18) Mar. 12.
The Five-Hundred-Foot Channel Span of the Clairton Bridge.* (14) Mar. 12.
Tower Foundations of the Manhattan Bridge Across the East River, New York Cit (14) Mar. 12.
Wooden Bridges and Trestles. (Committee Rept. to the Amer. Ry. Eng. and M. of Assoc.) (40) Mar. 18.
Renewal of a Bridge over Rondout Creek on the West Shore Railroad.* (40) Mar. 1
Connecticut Avenue Bridge, Washington.* (40) Mar. 18.
The Troitsky Bridge over the Neva, St. Petersburg.* (12) Mar. 18.
Improvement of a Plate Girder Bridge at Hartford, Conn.* Henry Robinson Bu (Paper read before the Connecticut Soc. of Civ. Engrs.) (13) Mar. 24.
A New Design of Truss with Pin and Riveted Connections.* (13) Mar. 24.
New Official Regulations for Railway Bridges in the Prussian State.* (12) Mar. 25.
The Plate-Girder Approaches of the Clairton Bridge.* (14) Mar. 26.
The Masonry Bridge at Plauen, Saxony.* Carl L. Palen. (14) Mar. 26.
Substructure Work and Erection of the Shubenacadie Bridge.* (14) Mar. 26.
Calculation of the Stresses and Design of Railway Structures of Steel Concrete.* Wal W. Colpitts. (40) Serial beginning Apr. 1.
The Construction of the Scherzer Lift Bridge at Newark Bay. (14) Apr. 2.
A One-Hundred Foot Pony-Truss Single-Track Through Span with Shallow Floor.* (Apr. 2.
Steel Piling for the Coffer-Dams of a Chicago Bridge.* (14) Apr. 2.
The Greenfield Street Railway Bridge. (14) Apr. 9.
The Proposed Ferry Bridge at Bordeaux.* (14) Apr. 9.
The Fireproof Floor of the Williamsburg Bridge, New York.* (14) Apr. 9.
A Cantilever Plate-Girder Highway Bridge.* (14) Apr. 9.

Electrical.

An Electric Percussive Rock-Drill.* Edward Dane. (74) Vol. 10.
The Use of Group-Switches in Large Power-Plants. L. B. Stillwell. (42) Jan.
Terminals and Bushings for High-Pressure Transformers. Walter S. Moody. (Jan.
Overhead High-Tension Distributing Systems in Suburban Districts. George H. Lu (42) Jan.
Automatic Apparatus for Regulating Generator and Feeder Potentials.* E. J. Bech (42) Jan.
Safeguards and Regulations in Operation of Overhead Distribution Systems. W. C Eglin. (42) Jan.
Speed-Torque Characteristics of the Single-Phase Repulsion Motor. Walter I. Slich (42) Feb.
The Mechanical Construction of Revolving-Field Alternators David B. Rushmore. (Feb.
A Contribution to the Theory of the Regulation of Alternators. H. M. Hobart an Punga. (42) Feb.
Repulsion Motor. Comfort A. Adams. (42) Feb.
Transformers in Repair Shops for Testing Armature and Field Coils.* (17) Mar.
The Riedler-Stumpf Steam Turbines.* Walter Rappaport. (26) Mar. 4.
The Equipment of an Engine Test House. R. K. Morcom. (Paper read before the I of Elec. Engrs.) (73) Mar. 4; Abstract (26) Mar. 25.
A New Method of Detecting Electrical Oscillations.* J. A. Ewing and L. H. Walt (Paper read before the Royal Society.) (73) Mar. 4.
Alternators in Parallel.* H. Bohle. (Paper read before the Inst. of Elec. Engrs.) (Mar. 4.
Some Applications of the Theory of Electrolysis to the Separation of Metals from Another.* A. Hollard. (73) Mar. 11.
The Rated Speed of Electric Motors as Affecting the Type to be Employed.* H. M. bart. (Paper read before the Inst. of Elec. Engrs.) (73) Serial beginning Mar. Abstract (26) Mar. 18; (11) Mar. 18.
The Electricity Works and Destructor of the Metropolitan Borough of Hackney.* (Serial beginning Mar. 11.
Calculation of Motor Starting Rheostats. F. Meurer and A. Simon. (27) Mar. 12.
The Design of Motor Starting Rheostats. Max Freimark. (27) Mar. 12.
The Choice of Wattmeters. H. P. Davis. (27) Mar. 12.
Electric Power Distribution in a Sash and Door Mill.* (27) Mar. 12.
The Electric Power and Transmission System of Schaffhausen, Switzerland.* (27) rial beginning Mar. 12.
Predetermination of Transformer Regulation.* Emerson G. Reed. (27) Mar. 12.

---

* Illustrated.

Electrical—(Continued).

Calculation of the Equivalent Ampere-Turns of Windings for Single and Polyphase Currents. C. F. Guilbert. (27) Mar. 12.
The Gas Engine for Central Station Service.* (27) Mar. 12.
Electric Traction for Freight Transportation in the Chicago Telephone Tunnels.* (13) Mar. 17.
Earth Connections. W. Moon. (26) Serial beginning Mar. 18.
Rubber Insulation. (15) Mar. 18.
A Central Station with Steam and Water Turbines, Zanesville, O.* (14) Mar. 19.
Electric Winding Engines* Maurice Georgi. (Paper read before the Inst. of Elec. Engrs.) (68) Mar. 19; (73) Mar. 18.
Reconstruction of the Zanesville, O., Railway, Light and Power Company's Property.* (27) Mar. 19; (17) Mar. 19.
On Turbo-Dynamos.* F. Niethammer. (27) Serial beginning Mar. 19.
Measurement of Internal Resistance of a Battery by Ohm's Method.* (27) Mar. 19.
Standardizing of Subway Manhole Construction. Hugh C. Baker, Jr. (27) Mar. 19.
Direct-Reading Measuring Instruments for Switchboard Use.* Kenelm Edgcumbe and Franklin Punga. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Serial beginning Mar. 25.
Power Supply in Sunderland.* (73) Mar. 25.
A Universal Shunt: J. Rymer-Jones Pattern.* (26) Mar. 25.
Some Uses of the Oscillograph. (Paper read before the Inst. of Elec. Engrs.) (26) Mar. 25.
Variable Speed Motors* J. W. Burleigh. (26) Mar. 25.
The Telephone Substation.* Arthur V. Abbott. (27) Serial beginning Mar. 26.
Vertical Motor-Generator Set.* (27) Mar. 26.
The Dialt Motor. N. H. Edgerton. (27) Mar. 26.
A Metrical Detector, for Electric Waves.* L. Heathcote Walter. (27) Mar. 26.
The Cost of Generating Electric Power. (14). Mar. 26.
Tests of Motor Driven Roller Tables at Duquesne. Albert Kingsbury. (20) Mar. 31.
The Hydro-Electric Stations of the Alta-Italia Company.* Enrico Bignami. (9) Apr.
New Electricity Works at West Ham.* (73) Apr. 1.
Recent Development in Metal Conduits for Electric Light Installations. L. M. Waterhouse. A. M Inst. C. E. (26) Apr. 1.
The Localization of Breaks in Submarine Cables. (26) Apr. 1.
Energy Distribution to Sub-Stations. C. Alfred Smith. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Apr. 1.
The Supply of Electricity to Small Towns. T. Tomlinson. (Abstract of Paper read before the Inst. of Elec. Engrs) (26) Apr. 1.
Electricity for Small Towns. G. Marshall Harriss. (26) Apr. 1.
The Shielded Balance.* G. A. Campbell. (27) Apr. 2.
Cables for Electric Light and Power. (27) Apr. 2.
Simultaneous Telephone and Telegraph Equipment.* Le Roy W. Stanton. (27) Apr. 2.
Electrolysis as Caused by the Railway Return Current.* Albert B. Herrick. (17) Apr. 2.
Booster Calculations. Wm. A. Del Mar. (27) Apr. 9.
Synchronous Converters. F. G. Baum. (27) Apr. 9.
Steam Turbine and Other Features of the Port Huron Light and Power Company's Station.* James E. Davidson. (27) Apr. 9.
La Réaction l'Induit dans les Alternateurs: Distorsion et Dispersion. C. F. Guilbert. (36) Serial beginning Feb. 25.
L'Accumulateur Edison.* (33) Mar. 26.

Marine.

Electric Power in British Shipyards. C. S. Vesey Brown, M. Inst. C. E. (10) Serial beginning Mar.
Possibilities of Design in Cargo Steamers. George Nicol. (10) Mar.
First-Class Armoured Cruiser *Argyle*.* (12) Mar. 18.
Superheating on Steamships. (12) Mar. 25.
The Twin-Screw Cable-Laying Steamer *Stephan*. (11) Serial beginning Mar. 25.
The Battleships *Triumph* and *Swiftsure*, Late *Libertad* and *Constitucion*. Sir Edward J. Reed. (Paper read before the Inst. of Naval Archts.) (11) Mar. 25.
Gyroscopic Effect of Fly-Wheels on Board Ship.* Otto Schlick. (Paper read before the Inst. of Naval Archts.) (11) Apr. 1; Abstract (12) Apr. 1
Some Results of Model Experiments. R. E. Froude. (Paper read before the Inst. of Naval Archts.) (11) Apr. 1.
Gas and Oil Engines for Marine Propulsion.* John E. Thornycroft. (Paper read before the Inst. of Naval Archts.) (47) Apr. 2; Abstract (12) Apr. 1; (11) Apr. 1.
Steam Turbine Propulsion for Marine Purposes.* A. Rateau. (Abstract of Paper read before the Inst. of Naval Archts.) (47) Apr. 2.
Étude sur les Générateurs Marins a Tubes d'Eau et a Grande Production. E. Duchesne. (32) Jan.

Mechanical.

Formulæ for Calculating the Size of Wire Ropes. Sheldon Smillie. (6) Jan.
Some Performance of Boilers and Chain Grate Stokers with Suggestions for Improvement.* A. Bement. (4) Feb.

* Illustrated.

Mechanical—(Continued).

Formulas for Proportioning the Raw Materials in Cement Manufacture. Richard K. Meade. (67) Feb.
Marl as Used in the Manufacture of Portland Cement. Ellis Soper. (67) Feb.
Distribution of Heat in a Rotary Kiln, Also Results of a Test of a Process for Utilizing Waste Heat from Rotary Cement Kilns. R. C. Carpenter. (From *Sibley Journal of Eng.*, Cornell Univ.) (67) Mar.
Coal and Coke-Handling Machinery of the Coke Plant of the Lackawanna Iron & Steel Co., at Lebanon, Pa.* Alfred Ernst. (45) Mar.
Power Required to Drive Machine Tools. (39) Mar.
By-Product Coke Plant of the Lackawanna Iron & Steel Co. at Lebanon, Pa.* W. B. Rothberg. (45) Mar.
The Coal Washer at Howe. Indian Territory.* W. R. Crane. (45) Mar.
The Compressed-Air Power Plant at the St. Louis Exposition.* (45) Mar.
Improvements in Economy of Pumping Engines. F. W. Dean. (28) Mar.
Gas Power for High-Pressure City Fire Service.* J. R. Bibbins. (10) Mar.
A Mexican Gas Power Plant. (62) Mar. 4.
The Equipment of an Engine Test House. R. K. Morcom. (Paper read before the Inst. of Elec. Engrs.) (73) Mar. 4.
The De Laval Steam Turbine.* T. C. Porte. (Abstract of Paper read before the Inst. of Elec. Engrs.) (73) Mar. 4.
Water Tube *v.* Flue Boilers. A. Hobbs. (Abstract of Paper read before the Manchester Assoc. of Engrs.) (22) Mar. 4; (11) Mar. 4.
The "Mork" Worm-Geared Pulley Block.* (22) Mar. 4.
Doors for Heating Pits. T. H. Lauder. (22) Mar. 4.
Weldless Tires for Vehicles.* (22) Mar. 4.
The Introduction of High-Speed Steels in Engineering Work-Shops.* Frank Fielden. (12) Mar. 4.
14-in. Hydraulic Boring Lathe. (12) Mar. 4.
Improvements in Steam Turbines.* (47) Mar. 5.
Superheating and Forced Lubrication. (47) Mar. 5.
A Two-Stroke Impulse Gas Engine.* (47) Mar. 5.
Water-Tube Boilers for Stationary Work. (47) Mar. 5.
Air-Lift Pumps. (47) Mar. 5.
The Gas Engine from the Manager's Standpoint.* H. W. True. (Paper read before the New England Assoc. of Gas Engrs.) (62) Mar. 10; (24) Apr. 11.
The Gallitzin Plant of the Pennsylvania Coal & Coke Company.* (16) Mar. 10.
Plant and Buildings of the Hecla Portland Cement & Coal Co.* (13) Mar. 10.
Calthrop & Brewer's Boilers for Motor-Wagons.* (11) Mar. 11.
Gas Explosions. L. Bairstow and A. D. Alexander. (11) Mar. 11.
A New High-Speed Triple-Expansion Engine.* (26) Mar. 11.
Enclosed Steam Engine and Dynamo.* (11) Mar. 11.
Travelling Blocks and Hoists.* (22) Mar. 11.
The Manufacture of Emery Wheels.* Waldon Fawcett. (19) Mar. 12.
The Tygard Reciprocating-Cylinder Double-Action Gasolene Motor.* (46) Mar. 12.
Limit Gauges for Machine Fits.* (47) Mar. 12.
Comparison of Calorimeters. J. S. S. Brame and Wallace A. Cowan. (47) Mar. 12.
Use of Stripping Plates in the Foundry.* (47) Mar. 12.
The Gas Engine for Central Station Service.* (27) Mar. 12.
The Works of the Egyptian Portland Cement Company.* (14) Mar. 12.
Comparative Boiler Tests with Ordinary and Pulverized Coal Firing. (14) Mar. 12.
Cement Burning. (Discussion at the meeting of the Assoc. of Portland Cement Mfrs.) (14) Mar. 12.
Inclines at New Bedford.* C. H. Gifford. (Paper read before the New England Assoc. of Gas Engrs.) (24) Mar. 14.
Inclines as Used at Lynn.* C. F. Prichard. (Paper read before the New England Assoc. of Gas Engrs.) (24) Mar. 14.
The Gypsum Plaster Industry of Kansas.* W. R. Crane. (16) Mar. 17.
The Terry Steam Turbine.* (20) Mar. 17.
The Green Fuel Economizer. A. H. Blackburn. (Paper read before the Philadelphia Foundrymen's Assoc.) (20) Mar. 17.
The Blast Furnace as the Sole Source of Power in a Modern Steel Works. (20) Mar. 17.
The Construction and Operation of Coal Piers.* (Abstract of Com. Rept. of Amer. Ry. Eng. and M. of W. Assoc.) (13) Mar. 17.
The Haesler Pneumatic Hammer.* (12) Mar. 18.
Steam Turbine of 11 000 Horse Power.* (46) Mar. 19.
The Riedler-Stumpf Steam Turbine. (14) Mar. 19; (47) Mar. 12.
Care and Management of Boilers. W. H. Fowler, M. Inst. C. E. (47) Mar. 19.
Recent Developments in Power Hammers.* H. F. Massey, M. I. Mech. E. (47) Mar. 19.
Manufacture and Use of High-Speed Tool Steel. J. M. Gledhill. (Paper read before the Coventry Eng. Soc.) (47) Serial beginning Mar. 19.
Some Practical Notes on Screws.* (47) Mar. 19.
Smoke Prevention. (47) Mar. 19.
Motor Fluid Generator.* Rudolf Berg. (62) Serial beginning Mar. 24.
High-Speed Steels in Engineering Workshops. Frank Fielden. (62) Mar. 24.
The Royal Gasoline Engine.* (20) Mar. 24.
The Knox Water Cooled Furnace Door.* (20) Mar. 24.

* Illustrated.

Mechanical—(Continued).

The New East Shop of the Westinghouse Electric & Mfg. Company.* C. C. Tyler. (Abstract from Elec. Club *Journal.*) (20) Mar. 24.
The "Sorts" Caster: A Type Casting Machine for Printers.* (20) Mar. 24.
The Boiler Plant, Saint Louis Exposition.* (40) Mar. 25.
Tool Grinding Machines. Joseph Horner. (11) Serial beginning Mar. 25.
The Diesel Engine. (26) Mar. 25.
Aerial Navigation. O. Chanute. (Paper read before the Amer. Assoc. for the Advancement of Science.) (19) Mar. 26.
Superheated Steam at a Water-Works Pumping Station.* (14) Mar. 26.
The Transmission of Power by Ropes.* Edwin Kenyon. (47) Mar. 26.
Test of a High-Speed Triple-Expansion Engine.* (47) Mar. 26.
Testing of Independent Water Heaters.* A. J. Campbell and George B. Leland. (Paper read before the New England Assoc. of Gas Engrs.) (24) Mar. 28.
The Motors of the Future.* Rudolf Berg. (62) Mar. 31.
Cleaning Steam Boilers. W. H. Wakeman. (62) Mar. 31.
A Comparative Steam-Pump Test with Saturated and with Superheated Steam. John Primrose. (13) Mar. 31.
Accurate Drill Jigs.* C. L. Goodrich. (20) Mar. 31.
A Large Spur Gear Cutter.* (20) Mar. 31.
A One-Belt Reversing Countershaft.* (20) Mar. 31.
Electric Wiring of Machine Tools.* O. W. Bodler. (39) Apr.
English and Swiss Drilling Machines for Boiler Shells.* Frank C. Perkins. (41) Apr.
The International Automobile Exposition at Paris.* Lucien Perissé. (9) Apr.
The Comparative Efficiency of Internally Fired and Externally Fired Boilers. D. W. Robb. (9) Apr.
Wire Rope Slope Haulage.* (45) Apr.
Splicing Wire Rope.* (45) Apr.
A New Design of Back-Geared Crank Shaper.* (25) Apr.
Motor-Driven Machine Tools. (25) Apr.
The Caskey Pneumatic Punch.* (41) Apr.; (21) Apr.
Suspension Cableways.* Andrew A. Bruch. (45) Apr.
Practical Points in the Construction and Use of Wire Rope. L. C. Moore. (45) Apr.
Wire Rope Haulage Problem.* Geo. S. Whyte. (45) Apr.
The Bleichert Wire-Rope Tramway.* (45) Apr.
Wire Rope Tramways.* J. H. Janeway, Jr. (45) Apr.
Hoisting Ropes. Geo. S. Whyte. (45) Apr.
The Transmission of Power by Wire Ropes.* W. H. Graves. (45) Apr.
Effects of Bending Stresses on Wire Rope. J. B. Richards. (45) Apr.
Wire Rope Tramway at Grand Encampment, Wyoming.* (45) Apr.
Wire Rope Calculations. (45) Apr.
The Nurnberg Gas Engine.* (64) Apr.
Gas Engines Using Wood-Gas.* (64) Apr.
Setting the Valves of the Brown Engine.* (64) Apr.
Briquetting Fuel Material. George E. Walsh. (64) Apr.
Pistons and Packing Rings.* (64) Apr.
Something about Piping.* W. H. Wakeman. (64) Apr.
Experiments to Determine the Advantages of Superheating. Emile Guarini. (64) Apr.
Reciprocating Sets *vs.* Turbo-Generators. I. William Chubb. (64) Apr.
The Selection and Testing of Lubricants. A. O. Doane. (64) Apr.
Lubricating Oils and Their Properties: How to Test Them and to Detect Adulterations. Wm. Davis. (64) Apr.
The Economy of Reciprocating Engines at Light Loads as Compared with That of Steam Turbines. J. A. Seymour (64) Apr.; (27) Apr. 2.
Messrs. Graham, Morton and Co.'s Works at Leeds.* (57) Apr. 1.
The Westinghouse Steam Turbine.* (73) Apr. 1.
Notes on Tests of Rapid-Cutting Steel Tools. C. Pendlebury. (12) Apr. 1.
The Wolseley Light Six-Horse-Power Motor-Car.* (11) Apr. 1.
Refrigeration from a Compressed-Air Motor. (14) Apr. 2.
Light Steel Gas Plant Roofs in England.* (14) Apr. 2.
Gearing of Motor-Driven Machinery.* (47) Apr. 2.
Improvements in Pneumatic Hammers.* (47) Apr. 2.
Comparative Boiler Tests. (62) Apr. 7.
Some Portland Cement Practice. (62) Apr. 7.
Two Suggestions for Exhaust Steam Heating.* William E. Wood. (13) Apr. 7.
High-Pressure Multi-Stage Turbine Pumps with Special Balancing Device.* (13) Apr. 7.
Some of the Reasons Why Separators Are Not Used in Portland Cement Works. Edwin C. Eckel. (13) Apr. 7.
The Steam Turbine and Its Field in Marine Work. H. C. Dinger. (46) Apr. 9.
The Pfeiffer Spring Motor.* (20) Apr. 7.
Warner Cut Meter.* (20) Apr. 7.
The Langen Two Speed Countershaft.* (20) Apr. 7.
Some Scotch Superheaters. (20) Apr. 7.
Reversing Valves for Regenerative Furnaces. A. D. Williams, Jr. (20) Apr. 7.
A 25-Ton Traveling Yard-Derrick.* (15) Apr. 8.

* Illustrated.

Mechanical—(Continued).

Steam Turbine and Other Features of the Port Huron Light and Power Company Station.* James E. Davidson. (27) Apr. 9.
Steam Turbine Plant of the Port Huron Light and Power Company.* (14) Apr. 9.
Power Production and Transmission in the Stuyvesant Elevator, New Orleans.* (14) Apr. 9.
Economy in Oxide Purification. H. L. Rice. (Paper read before the Ohio Gas Light Assoc.) (24) Apr. 11.
Note sur l'Aviation. J. Massau. (31) Pt. 4, 1903.
Étude sur les Fours Rotatifs pour la Cuisson du Ciment.* Poul Larsen. (36) Serial beginning Feb. 25.
Les Ciments de Laitier, Types Portland.* E. Bazin. (35) Mar.
Appareils de Nettoyage par le Vide.* (34) Mar.
Le Laboratoire de Mécanique du "Polytechnikum" a Zurich (Suisse).* (33) Mar. 5.
Installations Récentes de Grandes Magasins a Blé.* A. Bidault des Chaumes. (33) Mar. 26.

Metallurgical.

Sampling and Dry Crushing in Colorado.* Philip Argall. (74) Vol. 10.
A Method of Testing Cyanide Solutions Containing Zinc. Leonard M. Green. (74) Vol. 10.
The Titration, Use and Precipitation of Cyanide Solutions Containing Copper. Walter H. Virgoe. (74) Vol. 10.
A Dry Process for the Treatment of Complex Sulphide Ores. H. Livingston Sulman and Hugh Kirkpatrick Picard. (74) Vol. 10.
The Pierrefitte Concentrating Mill.* Mervyn S. Stutchbury. (74) Vol. 10.
Distortion and Rupture of Iron and Soft Steel. F. Osmond and G. Gartand. (62) Mar. 4.
Copper Losses in Blast Furnace Slags. William A. Heywood. (16) Mar. 10.
Foundry Practice with Copper and Its Alloys. W. J. Reardon. (Abstract of Paper presented before The Electric Club.) (62) Mar. 10.
Notes on Some Re-Grinding Machines. Martin Schwerin. (16) Mar. 10.
A Cantilever Battery Frame.* Ira C. Boss. (16) Mar. 10.
The Continuous Steel Process in the Open-Hearth Furnace.* (22) Mar. 11.
High-Speed Tool Steel: Its Manufacture and Use.* J. M. Gledhill. (Abstract of paper read before the Coventry Eng. Soc.) (12) Mar. 11.
Some Applications of the Theory of Electrolysis to the Separation of Metals from One Another.* A. Hollard. (73) Mar. 11.
The Slime Problem.* T. Lane Carter. (16) Mar. 17.
Bessemer Copper Converters. C. H. Glasser. (16) Mar. 17.
Hardening and Tempering Steel.* A. Stansfield. (Abstract of paper read before the Can. Ry. Club.) (15) Mar. 18.
Electrolytic Copper Refining. Wilder D. Bancroft. (Abstract of paper read before the Amer. Electrochemical Soc.) (68) Mar. 19.
On the Action of Limestone in Iron Cupolas. F. Wust. (From *Stahl und Eisen.*) (62) Mar. 24.
Notes on the Behavior of Zinc in the Blast Furnace. John J. Porter. (20) Mar. 24.
Laboratory Work under Smelting Conditions.* K. Friedrich. (16) Mar. 24.
The Electric Smelting of Complex Sulphides. A. A. Beadle. (16) Mar. 24.
A New Slime Table.* (16) Mar. 24.
The British Westinghouse Steel Foundry at Trafford Park, Manchester.* (22) Mar. 25.
Coloring of Metals. Paul Malherbe. (From the *Chronique Industrielle.*) (19) Mar. 26.
Converter Accessories.* C. H. Glasser. (16) Mar. 31.
Blast Furnace Gas As the Only Source of Power in Modern Steel Works. Karl Gruber. (From *Stahl und Eisen.*) (62) Mar. 31.
A New Process for Welding Aluminum.* (62) Mar. 31.
Alumino-Thermics, or the Production of High Temperatures by Burning Aluminum. E. Stütz. (3) Apr.
Recherches sur les Aciers au Chrome.* (33) Serial beginning Mar. 5.

Military.

The New Vickers-Maxim 9.2-Inch Wire-Wound Gun.* (46) Mar. 26.

Mining.

Gold Mining in Matabeleland.* G. R. Carey. (74) Vol. 10.
The Kaiping Coal Mines and Coal Field, Chihle Province, North China.* Herbert C. Hoover. (74) Vol. 10.
The Occurrence and Mining of Gold in the Dutch East Indies. S. J. Truscott. (74) Vol. 10.
The Hydraulic Installation at the Mines of the Compañia Minera de Panuco (Mexico).* Horace L. Short. (74) Vol. 10.
The Coal Washer at Howe, Indian Territory.* W. R. Crane. (45) Mar.
Electric Mine Locomotives: Traction, Third-Rail and Sprocket Locomotives. Wm. L. Affelder. (Paper read before the Western Penn. Cent. Min. Inst.) (45) Mar.
A Brief Outline of the Mining Department of the Hokkaido Colliery and Railway Co., Japan.* K. Yonekra. (45) Serial beginning Mar.

* Illustrated.

Mining—(Continued).

Shaft Sinking through Water-Bearing, Permian, Triassic and Cretaceous Strata.* (57) Mar. 4.
Polyphase Hauling Plant at Balsover Colliery.* (57) Mar. 4.
Fungi in Mining Timber.* Jules Elsner. (22) Mar. 4.
The Framing of Rectangular Shaft Sets.* Wilbur E. Sanders. (16) Mar. 10.
Endless Chain Winding in Vertical Shafts.* (57) Mar. 11.
Application of Electricity for Winding and Other Colliery Purposes. Maurice Georgi. (Abstract of Paper read before the Manchester Geol. and Min. Soc.) (22) Mar. 11.
Compound Cornish Cycle Pumping Engine (for Mines).* (11) Mar. 18.
Electric Winding Engines.* Maurice Georgi. (Paper read before the Inst. of Elec. Engrs.) (68) Mar. 19; (73) Mar. 18.
Electric Haulage in Mines. (47) Mar. 19.
Electric Power in Gold Dredging.* C. Weston Clark. (27) Mar. 19.
Gold Dredging under Difficult Conditions.* F. Winter Taylor. (16) Mar. 24.
Tailings Elevators.* W. H. Wood and E. J. Laschinger. (Abstract from the *Journal* of the Mech. Engineers' Assoc. of the Witwatersrand.) (16) Mar. 24.
A Note on the Construction of Mine Bulkheads. William Thompson. (Paper read before the Can. Min. Inst.) (16) Mar. 24.
Cableways for Open-Pit Mining.* Spencer Miller; M. Am. Soc. C. E., M. Am. Inst. M. E. (45) Apr.
Notes on Mine Ropes.* Charles W. Comstock. (45) Apr.
The Coal Fields of Crow's Nest Pass, British Columbia.* E. Jacobs. (9) Apr.
The Mechanical Equipment of Collieries. George H. Winstanley. (Abstract of Paper read before the Manchester Geol. and Min. Soc.) (16) Apr. 7.
Accumulateur de Vapeur, Système Rateau: Installation Faite aux Mines de Bruay.* Ch. Dantin. (33) Mar. 12.

Miscellaneous.

The Inch Unit System. Thomas Parker. (11) Mar. 4.

Municipal.

Gas Power for High-Pressure City Fire Service.* J. R. Bibbins. (10) Mar.
Machine-Mixed Concrete as Applied to Street Work.* D. G. Fisher. (13) Mar. 10.
High-Pressure Water Service for Fire Protection in New York. Nicholas S. Hill. (Abstract of Rept. to John T. Oakley, Commr., Dept. of Water Supply, Gas & Electricity.) (14) Mar. 19; Report (13) Mar. 24.
Details of Street Pavements in Salt Lake City, Utah.* (14) Mar. 26.
Street Pavements. Louis M. Pfeiffer. (Abstract of Paper read before the Colorado Pol. Assoc.) (60) Apr.
The Use of High Pressure Gas in Street Lighting. J. J. Knight. (Paper read before the Ohio Gas Light Assoc.) (24) Apr. 11.

Railroad.

Proposed Improvements in St. Louis Terminals.* A. P. Greensfelder. (Paper read before the Engineers' Club of St. Louis.) (1) Jan.
Square Roundhouses.* Geo. P. Nichols. (61) Feb. 16.
The lubrication of Locomotive Valves and Cylinders. D. R. MacBain. (61) Feb. 16.
Ventilating System in Blacksmith Shop, Northern Pacific Railway.* (39) Mar.
Renewal of the Car Department at the Portsmouth Shops: Seaboard Air Line Railway.* (39) Mar.
Railroad Shop Tools.* Charles H. Fitch. (39) Mar.
Snow Screens and Fences.* R. S. Scholefield, Assoc. M. Inst. C. E. (21) Mar.
Simple Freight Locomotive, N. Y. C. & H. R. R. R.* (39) Mar.
American Freight Car Bogies.* (21) Mar.
Power Station, Rolling Stock and Dispatching System of the Pacific Electric Railway Company.* (17) Mar.
Electric Railways of Ohio.* (17) Mar.
Electro-Pneumatic Signalling at Bolton: Lancashire and Yorkshire Railway.* (21) Mar.
20-Ton Covered Wagons: Great Northern Railway of Ireland.* (21) Mar.
Heavy Continental Passenger Tank Engines.* (21) Mar.
Compressed Acetylene for Lighting Railway Carriages. E. G. Fisher. (Abstract of Paper read before the International Acetylene Assoc.) (21) Mar.
French System of Heating Railway Carriages.* (21) Mar.
Trials of Quick-Acting Railway Brakes. (12) Mar. 4.
The Albula Railway.* (11) Serial beginning Mar. 4.
Trials of the Great Western French Engine. Charles Rous-Marten. (11) Mar. 4.
Distribution of Loads on Locomotive Axles. A. T. J. Kersey. (12) Mar. 11.
Atlantic Locomotive for the Northeastern Railway of England.* (40) Mar. 11.
The Railways of Canada since 1867. G. W. P. Atkinson. (40) Mar. 11.
Four-Cylinder Compound Locomotive for the Atchison, Topeka and Santa Fé Railway.* (11) Mar. 11.
Blocking Up Track in Severe Cold Weather.* (15) Mar. 11.
Wrecking Outfits on the Pennsylvania. (15) Mar. 11.
The Wabash Extension into Pittsburg.* (15) Mar. 11.

* Illustrated.

Railroad—(Continued).

Pennsylvania Low-Grade Line Down the Susquehanna. (15) Mar. 11.
Steel Railroad Substructure.* (15) Mar. 11.
New Shops of the P., B. & W. at Wilmington.* (15) Mar. 11.
The Water Stations of the Chicago & Alton.* (15) Mar. 11.
Pillar Drains for Holding Banks.* (15) Mar. 11.
The Lawson Dump Car.* (15) Mar. 11.
The Chicago, Indianapolis & St. Louis Short Line.* F. W. Smith. (15) Mar. 11.
The New Freight Terminal of the Monon at Louisville.* (15) Mar. 11.
Baltimore & Ohio Export Pier at Locust Point.* (15) Mar. 11.
Gulf & Ship Island R. R., Harbor and Terminal Improvements at Gulfport, Miss.* (18) Mar. 12.
Block Signaling on Single Track. (18) Mar. 12.
Dirt and Ballast Spreading Cars, T., P. & W. Ry.* (18) Mar. 12.
The Hayes Lifting Derail.* (18) Mar. 12.
Some Track Work in Changing Gage.* (18) Mar. 12.
New Engine House Construction on the Intercolonial Ry.* (18) Mar. 12.
Terminal Necessities. (18) Mar. 12.
Modern Wrecking Appliances.* (18) Mar. 12.
The Ravlin System of Electric Wiring of Round Houses and Shops.* (18) Mar. 12.
Maintenance of Way Standards of the Hokkaido Coal Mine Ry.* (18) Mar. 12.
Performance of Automatic Signals in Cold Weather.* H. S. Balliet. (Paper presented before the Railway Signal Assoc.) (18) Mar. 12.
A New Derail for Side Tracks.* (13) Mar. 17.
The Construction and Operation of Coal Piers.* (Abstract of Com. Rept. of Amer. Ry. Eng. and M of W. Assoc.) (13) Mar. 17.
Atlantic Type Passenger Locomotives for the Wabash Railway.* (13) Mar. 17.
The Location of the First Division of the Hankow-Canton Ry. Jesse W. Miller. (13) Mar. 17.
The Mantua Freight Transfer House of the Pennsylvania Railroad.* (40) Mar. 18.
A Staff Block System for High Speed Trains.* (40) Mar. 18.
The Union Terminal Arrangements at Washington.* (40) Mar. 18.
Ventilation of Baltimore Tunnel, P., B. & W. Ry.* (40) Mar. 18.
Reduction of Gradient and Elimination of Distance, Curvature, and Rise and Fall on Union Pacific Railroad. J. B. Berry. (Paper presented before the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18; Abstract (15) Mar. 25; (13) Apr. 7.
Lehigh Valley Shops at Sayre, Pa.* (15) Mar. 18.
New Passenger and Freight Terminals at Atlanta, Ga. (15) Mar. 18.
New Freight Yard of the Lake Shore at Elkhart, Ind.* (15) Mar. 18.
Speed Tests of the De-Glehn Compound on the Great Western of England. (15) Mar. 18.
The Railway Electrification Problem and Its Probable Cost for England and Wales. F. F. Bennett. (Paper read before the Inst. of Elec. Engrs.) (73) Mar. 18; Discussion (73) Mar. 25; Abstract (26) Apr. 1; (47) Serial beginning Mar. 12.
Proposed Block Signals on the Southern Pacific.* (40) Mar. 18.
The Efficiency of the High-Speed Brake. (40) Mar. 18.
The Electrification of the Liverpool and Southport Railway.* (11) Mar. 18; (73) Serial beginning Mar. 18; (26) Serial beginning Mar. 18; (12) Mar. 18; (47) Mar. 19; (17) Apr. 2.
Combustion Chambers in Italian Locomotives.* (12) Mar. 18.
New Six-Coupled Express Engine for the Great Western Railway.* Charles Rous-Marten (12) Mar. 18.
Ballast. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (14) Mar. 26; (40) Mar. 18.
Rail. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18.
Track. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18.
Buildings. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18.
Masonry. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18.
Water Service. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18.
Roadway. (Committee Rept. to the Amer. Ry. Eng. and M. of W. Assoc.) (40) Mar. 18.
Iron and Steel Structures. (Committee Rept. to the Amer. Ry. Eng. and M. of. W. Assoc.) (40) Mar. 18.
The Canadian Pacific Railway Shops at Montreal.* (14) Serial beginning Mar. 19.
Improved and Combination Collapsible Pile Drivers for Railroad Work.* (14) Mar. 19.
De Glehn Compound for the Great Western Railway, England.* (46) Mar. 19.
Yards and Terminals. (From a Committee Report presented before the Amer. Ry. Eng. and M. of W. Assoc.) (18) Mar. 19; (40) Mar. 18; (13) Mar. 24; (15) Mar. 18.
Ties. (Committee Report to the Amer. Ry. Eng. and M. of W. Assoc.) (18) Mar. 19; (13) Mar. 17; (40) Mar. 18.
Report on Proposed Pan-American Ry. (18) Mar. 19.
Track Inspection Car on the Northern Railway of France.* (13) Mar. 24.
The Proposed New Railway Lines for the Development of the Port of Genoa, Italy.* Charles R. King. (13) Mar. 24.
Ventilation of Baldwin Locomotive Works Engine House.* (40) Mar. 25.

---

* Illustrated.

Railroad—(Continued).

New Electromagnetic Track Brake.* (73) Mar. 25.
Improvements on the Denver & Rio Grande.* (15) Mar. 25.
Performance of Automatic Block Signals under Unfavorable Conditions. H. S Balliet (15) Serial beginning Mar. 25.
Water Supply for Railroads. (Abstract of Report to the Amer. Ry. Eng. and M. of W. Assoc.) (15) Mar. 25.
New Automatic Block Signals on the Southern Pacific.* (15) Mar. 25.
Maintenance of Way Improvements on the New York, Ontario & Western Ry.* (18) Mar. 26.
Consolidation Engines for Japan.* (18) Mar. 26.
Gas Engines in Railway Work. (18) Serial beginning Mar. 26.
Refrigerator Cars for Pabst Brewing Co.* (18) Mar. 26.
The Dick System of Lighting Trains by Electricity.* (19) Mar. 26.
Recent Investigations with Treated Ties. Hermann von Schrenck. (From Rept. of Com. on Ties of Amer. Ry. Eng. and M. of W. Assoc.) (14) Mar. 26.
Four-Cylinder Balanced Compound Locomotives: Atchison, Topeka & Santa Fe Ry.* (13) Mar. 31.
A Protected Sectional Third-Rail System of Electric Traction.* (13) Mar. 31.
The Appraisement of the Physical Value of Wisconsin Railways for the Purpose of Taxation. W. D. Taylor, M. Am. Soc. C. E. (Abstract of Paper in *Wisconsin Engr.*) (13) Mar. 31.
French Locomotive for the Pennsylvania R. R.* (13) Mar. 31.
A Powerful Passenger Locomotive: 4-6-2 (Pacific Type): Chicago & Alton Railway.* (25) Apr.
Passenger Locomotive for the Vandalia: 4-4-2 (Atlantic) Type.* (25) Apr.
A Visit to the Works of J. G. Brill Company.* (25) Apr.
An Object Lesson in Firebox Side Sheets.* (25) Apr.
The Corrington Air Brake.* (25) Apr.
The Lawson Improved Dumping Car.* (25) Apr.
New Shops of the Terminal Railroad Association of St. Louis, at East St. Louis, Ill.* (39) Apr.
Freight Locomotive: Southern Railway.* (39) Apr.
New Cars for the Milwaukee Refrigerating Transit Company.* (39) Apr.
Passenger Locomotive, Union Pacific Railway.* (39) Apr.
30-Ton "Cantilever" Coal Wagons: Great Central Railway.* (21) Apr.
Four-Cylinder Compound Engine: Southern Railway of Italy.* (21) Apr.
The Sperry-Lyndon Electric Lighting System for Trains. (21) Apr.
Economical Locomotives.* Charles R. King. (21) Apr.
Ten-Wheeled Radial Tank Engine: Lancashire and Yorkshire Railway.* (21) Apr.
Express Engines "Albion" and "La France": Great Western Railway.* (21) Apr.
London and North-Western Carriage Works, Wolverton.* (11) Apr. 1.
Safety Appliances. George Grooby. (Abstract of Paper read before the New-England R. R. Club.) (15) Apr. 1.
Underground Brooklyn Terminal of the Long Island Railroad.* (15) Apr. 1.
Revision of Grades and Double-Tracking on the Richmond, Fredericksburg and Potomac.* (15) Apr. 1.
Fifty-Ton Steel Underframe Flat Car.* (15) Apr. 1.
The Corrington Alternate Quick-Acting Brake System.* (18) Apr. 2; (40) Apr. 1; (15) Apr. 1.
Delaware, Lackawanna & Western Coach.* (18) Apr. 2.
Comparative Tests of Locomotives Using Saturated and Superheated Steam.* Strahl. (Abstract from *Zeitschrift* des Vereins Deutscher Ingenieure.) (47) Apr. 2.
The Mendelbahn.* (17) Apr. 2.
The Hudson River Tunnel.* (19) Apr. 2.
An Electrified English Steam Railroad.* (27) Apr. 2.
Electromagnetic Track Brake.* (27) Apr. 2.
Railway Location in the Florida Everglades.* William J. Krome. (14) Serial beginning Apr. 2.
New Tie-Preserving Processes. Hermann von Schrenck. (From Report of Com. on Ties of Am. Ry., Eng. and M. of W. Assoc.) (14) Apr. 2.
The Wilmington Shops of the Pennsylvania.* (40) Apr. 8.
Consolidation (2-8-0) Locomotive for the Delaware & Hudson.* (15) Apr. 8.
Compound Locomotives in France. (15) Apr. 8.
Saddle Tank Culm-Burning Locomotive.* (18) Apr. 9.
All Steel Railway Substructure.* (17) Apr. 9.
Appareil Servant à Montrer les Perturbations des Locomotives en Marche.* (36) Feb. 25.
Expériences sur le Rendement des Locomotives: Locomotive à Distribution Bonnefond. Joseph Nadal. (38) Mar.
Les Automotrices du Taff Vale Railway et du Great Western Railway.* R. Bonnin. (36) Mar. 10.
Aération du Tunnel de l'Albespeyre (Lozère); Ventilateurs E. Farcot.* (33) Mar. 12.
Le Chemin de Fer Électrique du Vésuve.* Jules Couchepin. (33) Mar. 19.
Le Chemin de Fer Transhellénique.* (33) Mar. 26.

* Illustrated.

Railroad, Street.

The Alternating-Current Railway Motor.* Charles P. Steinmetz. (42) Feb.
Single-Phase Railways.* W. A. Blanck. (42) Feb.
The Graphical Calculation of Flange Stresses in Girders and Trusses.* Oscar Sanne. (4) Feb.
Convertible Cars Operated in Toronto.* (17) Mar.
Bath Electric Tramways.* (26) Mar. 4.
The Mersey Railway: Multiple Control. H. L. Kirker. (Abstract of Paper read before the Inst. of Elec. Engrs.) (26) Mar. 11.
Single-Phase Railroads.* (18) Mar. 12.
Progress on the East Boston Subway.* (18) Mar. 12.
The Boston Transit Problem.* (40) Mar. 18.
Reconstruction of the Zanesville, O., Railway, Light & Power Company's Property.* (27) Mar. 19; (17) Mar. 19.
Repair Shop Practice of the Pacific Electric Railway Company.* (17) Mar. 19.
New Power Plant at Cranford.* (17) Mar. 19.
Street Car Lubrication. George L. Fowler. (17) Mar. 19.
Fused Steel-Tired Wheels.* (17) Mar. 19.
The Cranford Plant of the Public Service Corporation of New Jersey.* (14) Mar. 19.
The Hudson River Tunnel.* (46) Mar. 26.
Steel-Tired Wheels on the Boston Elevated Railway System.* (17) Mar. 26.
The Westinghouse Single-Phase Railway System.* (17) Mar. 26.
Electrolysis as Caused by the Railway Return Current.* Albert B. Herrick. (17) Apr. 2.
The Dunedin (New Zealand) Tramways.* (17) Apr. 2.
The Westinghouse Single Phase Motor.* (15) Apr. 8.
Notes on Los Angeles Railway Company's System.* (17) Apr. 9.
The Evansville & Princeton Traction System.* (17) Apr. 9.
Single versus Multiphase Generators in Alternating Current Railway Work, W. A. Blanck. (17) Apr. 9.
Note sur l'Emploi de la Double Traction. M. Herdner. (38) Mar.
Traction Électrique par Courant Alternatif Simple: Système Finzi.* (33) Mar. 5.
Locomotive Électrique et Prise de Courant pour Ligne Aérienne, des Ateliers d'Oerlikon. (33) Mar. 12.

Sanitary.

Heating from a Central Station.* W. H. Pearce. (4) Feb.
Ventilating System in Blacksmith Shop, Northern Pacific Railway.* (39) Mar.
Plumbing in the Hotel Wellington, New York.* (70) Mar.
The Battery System of Warm-Air Heating.* C. E. Oldacre. (Paper read before the A. S. H. and V. E.) (70) Mar.
A New Jointing Material, Sulphur and Sand, for Sewer Pipes. Alexander Potter. (13) Mar. 10; (14) Mar. 12.
An American Sewage Pumping Engine.* (12) Mar. 11.
The Electric Works and Destructor of the Metropolitan Borough of Hackney. (26) Serial beginning Mar. 11.
The Cleaning and Flushing of Sewers. (14) Mar. 12.
A Large Concrete and Brick Storm Sewer in Newark, N. J.* (14) Mar. 12.
Ventilating and Heating the Franklin Square Theatre, Worcester, Mass.* (14) Mar. 26.
Sewage Pumping Plant for the Jackson Park Ave. Sewage District at Chicago.* (13) Mar. 31.
Refuse Destruction in Burnley, England.* (60) Apr.
Reclamation of the Marshes of New Jersey and Staten Island.* Henry Clay Weeks. (13) Apr. 7.
Combined Steam and Hot Water Radiation.* (14) Apr. 9.

Structural.

Ferroinclave: A Fireproof Building Material.* H. F. Cobb. (Paper read before the Civil Engineers' Club of Cleveland.) (1) Jan.
The Preservation of Wood from Fire and Decay. Joseph L. Ferrell. (4) Feb.
The Siegwart Ferro-Concrete Floor Beams.* (62) Mar. 4.
The Collapse of the Darlington Apartment House in New York City.* (13) Mar. 10.
Fireproof Buildings in the Rochester Fire.* (13) Mar. 10.
Tests of the Adhesion and Initial Stress of Steel in Concrete. Sam W. Emerson. (13) Mar. 10.
Protection of Steel from Rust by Concrete. Charles L. Norton. (Extract from Report of the Insurance Eng. Experiment Station.) (62) Mar. 10.
Commercial Tests of Material. E. G. Izod. (Paper read before the Eng. Soc., Univ. College, Lond.) (11) Mar. 11; (62) Apr. 7.
Strength of Piles. C. S. Bihler. (Paper read before the Pacific Northwest Soc. of Engrs.) (18) Mar. 12.
The Darlington Hotel Collapse, in New York City.* (14) Mar. 12.
The Lessons of the Rochester Fire.* (20) Mar. 17.
The Design of Reinforced Concrete Beams.* (Abstract of Report by Com. on Masonry, Amer. Ry. Eng. and M. of W. Assoc.) (13) Mar. 17.
Hollow Block Concrete Wall Construction.* H. W. Cowan. (40) Mar. 18.

* Illustrated.

Structural—(Continued).

The Importance of Adopting Standard Sizes of Test-Bars for Determining the Strength of Cast Iron.* Alexander E. Outerbridge, Jun. (From *Proceedings* of Amer. Soc. for Testing Materials.) (11) Mar. 18.
Reinforced Concrete in the Baltimore Fire.* (14) Mar. 19.
Foundations of the Rogers Building, New York.* (14) Mar. 19.
Views of E. C. Shankland of Chicago Concerning Steel Structures in the Baltimore Fire.* (20) Mar. 24.
Report to the Chief of Engineers, U. S. A., on the Baltimore Fire. John Stephen Sewell. (13) Mar. 24.
The Planning of Factory Buildings and the Influence of Design on Their Productive Capacity. Hugo Diemer. (13) Mar. 24.
Concrete Piling.* (46) Mar. 26.
The Fallacy of the Tests Ordinarily Applied to Portland Cement. Richard K. Meade. (Paper read before the Amer. Chem. Soc.) (14) Apr. 2.
New Appliances for Re-Roofing Shops without Stopping Work.* (19) Apr. 2.
A Unique Case of Shoring Work on a New York Telephone Building.* (13) Apr. 7.
Cross-Bending Tests on Steel-Concrete Beams.* (15) Apr. 8.
Safeguarding the Foundations of Trinity Church Spire, New York City.* (14) Apr. 9.
A Concrete Mixing Plant for a Power House Foundation.* (14) Apr. 9.
The Canadian Pacific Grain Elevator at Port Arthur, Ontario.* (14) Apr. 9.
Le Marbre Artificiel.* A. Herne. (36) Feb. 25.
Petite Maison de Rapport, Villa Deshayes (Rue Didot), à Paris.* E. Rivoalen. (35) Mar.
Petit hôtel, 326, Rue Saint-Jacques. à Paris.* (35) Mar.
Installations Récentes de Grandes Magasins a Blé.* A. Bidault des Chaumes. (33) Mar. 26.

Topographical.

Desirable Features in a Transit for Topographical Surveys.* Geo. Jacob Davis, Jr. (13) Mar. 31.
A New Slide Rule.* (12) Apr. 1.

Water Supply.

Piping for Hydraulic Machinery. Frank B. Kleinans. (30) Mar.
Rainfall and Run-Off from Catchment Areas in New England.* L. M. Hastings. (28) Mar.
Thawing Frozen Service Boxes, Pipes, etc.: Topical Discussion. (28) Mar.
Notes on the Construction of a Storage Reservoir. W. H. Richards. (28) Mar.
Requisite Amount of Water for a Public Supply.* J. Herbert Shedd. (28) Mar.
Hydro Electric Installation at Newry.* (12) Mar. 4.
Water-Distilling Plant for Egypt.* (11) Mar. 4.
The Contraction of Jets.* John Goodman, M. Inst. C. E (11) Mar. 11.
Water-Power Development at York Haven, Pa.* (14) Mar. 12.
Water Purifying Plants in Germany.* (18) Mar. 12.
An Irrigated Sugar Plantation in the Sandwich Islands. C. H. Kluegel. M. Am. Soc. C. E. (13) Mar. 17.
Repairs of the Water-Works Pumping Station at Evansville, Ind. (13) Mar. 17.
Experience in Thawing Water Pipes by Electricity. (13) Mar. 17.
Kirtland Street Pumping Station of the Cleveland Water-Works.* Charles Goffing. (14) Mar. 19.
The Measurement, Consumption and Waste of Water in the Boston Metropolitan District. (14) Mar. 19.
A Filtration Plant for Harrisburg, Pa. (14) Mar. 19.
Hign-Pressure Water Service for Fire Protection in New York. Nicholas S. Hill. (Abstract of Rept. to John T. Oakley, Commr., Dept. of Water Supply, Gas and Electricity.) (14) Mar. 19; Report (13) Mar. 24.
A Cast-Iron Meter Box * Edward H. Cowan. (13) Mar. 24.
Report on Proposed High Pressure Fire Service for Borough of Brooklyn, New York City.* I. M. de Varona, M. Am. Soc. C. E. (13) Mar. 24.
A Water Main Tapping Machine.* (12) Mar. 25.
Water Supply for Railroads. (Abstract of Report to the Amer. Ry. Eng. and M. of W. Assoc.) (15) Mar. 25.
Steel-Concrete Standpipe at Milford, Ohio.* (14) Mar. 26.
A Concrete-Steel Reservoir for East Orange, New Jersey.* (14) Mar. 26.
Mechanical Devices for the Purification of Water.* (41) Apr.
The Location of Electric Water-Power Stations.* Alton D. Adams. (10) Apr.
Softening and Purifying Water for Boilers. J. C. W. Greth. (10) Apr.
Village Water Works of Geneva, Ohio.* (14) Apr. 2.
Water Power Transmission Plant at Elliott's Falls, Ontario.* Charles L. Fitch. (27) Apr. 2.
Rebuilding the Portman Dam near Anderson, S. C.* John L. Sheppard, Jr. (14) Apr. 2.
Discharging Capacity of Culverts.* Washington Parker Ireland. (14) Apr. 2.
The Five Dams and Wood Stave Conduit of the Southern California Mountain Water Co.* (13) Apr. 7.

* Illustrated.

Water Supply—(Continued).

The Barossa Arched Concrete Dam in South Australia.* (13) Apr. 7.
Levi Mechanical Filters at Charleston-Kanawha, W. Va.* (13) Apr. 7.
The Derwent Valley Water-Works System, Derbyshire.* (14) Apr. 9.
Recent Concrete-Steel Water-Works Construction at Ithaca, N. Y.* (14) Apr. 9.
Alimentation de Paris en Eau Potable. J. Bergeron. (32) Jan.
La Stérilisation des Eaux par l'Ozone. (36) Feb. 25.
Élévation Directe des Liquides par l'Air Comprimé.* E. Lemaire. (33) Mar. 19.

Waterways.

Timber Crib Foundations.* George B. Francis. (1) Feb.
The Hydraulic Lock on the Trent Canal at Peterborough. Walter J. Francis, M. Can. Soc. C. E. (15) Mar. 25.
The Canalization of the Elbe and the Moldau.* (19) Mar. 26.
Cylindrical Movable Dams at Schweinfurt, Germany.* (14) Mar. 26.
Pitot Tubes, with Experimental Determinations of the Form and Velocity of Jets. James E. Boyd and Horace Judd. (Paper read before the Amer. Assoc. for the Advancement of Science.) (13) Mar. 31.
The Barge Canal across New York State.* (15) Apr. 8.
Barrages Mobiles Cylindriques à Grande Portée-Barrages de Schweinfurt (Allemagne).* René Koechlin. (33) Feb. 27.
Le Port de Cette.* Francis Marre. (36) Serial beginning Mar. 10.

* Illustrated.

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

May, 1904.

PROCEEDINGS - VOL. XXX—No.

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

Published at the House of the Society, 220 West Fifty-seventh Street, New
the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15t

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXX. No. 5.

MAY, 1904.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1904.

American Society of Civil Engineers.

OFFICERS FOR 1904.

President, CHARLES HERMANY.

Vice-Presidents.

Term expires January, 1905:	*Term expires January, 1906:*
L. F. G. BOUSCAREN,	F. S. CURTIS,
JAMES D. SCHUYLER.	S. L. F. DEYO.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1905:	*Term expires January, 1906:*	*Term expires January, 1907:*
RICHARD S. BUCK,	ALFRED CRAVEN,	CHARLES S. GOWEN,
GEORGE H. PEGRAM,	JOSEPH O. OSGOOD,	NELSON P. LEWIS,
WILLIAM J. WILGUS,	GEORGE S. DAVISON,	JOHN W. ELLIS,
WILLIAM JACKSON,	E. C. LEWIS,	GEORGE S. WEBSTER,
EDMUND F. VAN HOESEN,	HUNTER McDONALD,	RALPH MODJESKI,
JAMES L. FRAZIER.	ELWOOD MEAD.	CHARLES D. MARX.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
S. L. F. DEYO,	GEORGE H. PEGRAM,	NELSON P. LEWIS,
L. F. G. BOUSCAREN,	ALFRED CRAVEN,	WILLIAM JACKSON,
RICHARD S. BUCK,	JOSEPH O. OSGOOD,	E. C. LEWIS,
WILLIAM J. WILGUS,	GEORGE S. DAVISON,	RALPH MODJESKI,
CHARLES S. GOWEN.	HUNTER McDONALD.	CHARLES WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—L. F. G. Bouscaren, C. W. Buchholz, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Joseph T. Richards, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - - 583 Columbus.
CABLE ADDRESS, - - - - - "Ceas, New York."

[AME]RICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

[...] is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

[...], 1904.—The meeting was called to order at 8.45 P. M.; [...] North, M. Am. Soc. C. E., in the chair; Chas. Warren [...]tary; and present, also, 146 members and 25 guests.

[...]utes of the meetings of April 6th and 20th, 1904, were ap[...]rinted in the *Proceedings* for April, 1904.

[...] entitled "The Lake Cheesman Dam and Reservoir," by [...] Harrison, M. Am. Soc. C. E., and Silas H. Woodard, Assoc. [...]. C. E., was presented by Mr. Harrison, and illustrated with [...]es.

The paper was discussed by Messrs. G. S. Williams, E. Sherma Gould, E. W. Harrison, Emil Kuichling, Edward Wegmann, J. Wald Smith and Charles L. Harrison.

The Secretary announced the receipt of written discussions fro Messrs. J. P. Frizell, Burr Bassell, F. B. Maltby, Frank C. Horn an Charles S. Gowen, but owing to lack of time these were not read.

Ballots for membership were canvassed, and the following cand dates elected.

As Members.

Jeremiah Ahern, Washington, D. C.
Walton Irving Aims, New York City.
Charles Hopkins Cartlidge, Chicago, Ill.
Roderick Greene Collins, Jr., New York City.
Arthur Warren Dean, Concord, N. H.
Guy Carleton Emerson, Boston, Mass.
Halbert Powers Gillette, New York City.
Homer Hamlin, Los Angeles, Cal.
Joseph Gales Holcombe, Manila, Philippine Islands.
Charles Mattathias Jacobs, New York City.
William Henry Jones, Leavenworth, Kans.
Edward Marion Kenly, Austen, W. Va.
Walter Danville Lovell, Des Moines, Iowa.
Henry Vincent Macksey, Boston, Mass.
Robert Bradford Marshall, Sacramento, Cal.
George Nauman, Harrisburg, Pa.
Edwin Rufus Quinby, New York City.
Henry Linton Reber, St. Louis, Mo.
Everett Edward Stone, Springfield, Mass.
Joseph Thompson Stuart, Chester, Pa.
John Edward Swanker, Middlesbrough, England.
Benjamin Henry Taylor, Edgewood Park, Pa.
Joseph Franklin Witmer, Buffalo, N. Y.

As Associate Members.

Hugh Cossart Baker, Jr., New York City.
John Mansfield Belknap, San Juan, Porto Rico.
Charles Ferdinand Brenn, Roslyn, Wash.
William Laramy Butcher, Boston, Mass.
Roscoe Nathaniel Clark, Hartford, Conn.
John Baptiste Clermont, New York City.
James Lyford Davis, New York City.
Albert Emerson Greene, Ann Arbor, Mich.

John Clayton Hoyt, Washington, D. C.
Robert Hyde Jacobs, New York City.
William Bard Johnstone, New York City.
Oscar Francis Lackey, Santiago, Cuba.
Charles Orton Lasley, Toledo, Ohio.
Robert Leathan Lund, Nashville, Tenn.
John Henry Madden, New York City.
Harry Hayes Robinson, Portland, Me.
James Forrest Sanborn, Brooklyn, N. Y.
Oscar James West, Chicago, Ill.
Wilkie Woodard, Shreveport, La.
Andrew Alfred Woods, Jr., Vicksburg, Miss.

As Associate.

Richard Roswell Lyman, Ithaca, N. Y.

The Secretary made the following announcements:

The transfer of the following candidates, by the Board of Direction, on May 3d, 1904:

From Associate Member to Member.

Richard Lewis Humphrey, Philadelphia, Pa.
John Cranch Moses, Cambridge, Mass.
Frank Herbert Snow, Boston, Mass.
Clement Isaac Walker, New York City.
Frederick Conover Warman, Washington, D. C.
Walter Loring Webb, Philadelphia, Pa.

From Associate to Associate Member.

Charles Henry Umstead, Lawrence, Mass.

The election of the following candidates, by the Board of Direction, on May 3d, 1904:

As Juniors.

Laurence Adams Ball, New York City.
Ralph Weller Greenlaw, New York City.
Albert Preston Greensfelder, St. Louis, Mo.
Edward Joseph Gugerty, New York City.
Gage Haselton, Boston, Mass.
Robert Hall Merrill, Grand Rapids, Mich.

The following deaths:

Danforth Hurlbut Ainsworth, elected Member, March 3d, 1886 died April 24th, 1904.

Charles Storer Storrow, elected Honorary Member, January 24th 1893; died April 30th, 1904.

James W. Ainslie, elected Fellow, May 28th, 1872; died Septembe 13th, 1902.

Adjourned.

May 18th, 1904.—The meeting was called to order at 8.45 P. M. Past-President Alfred Noble in the chair; Chas. Warren Hunt, Secre tary; and present, also, 156 members and 44 guests.

A paper, entitled "The Gatun Dam," by C. D. Ward, M. Am Soc. C. E., was presented by the author and discussed by Charles L Harrison, M. Am. Soc. C. E., and the author.

A second paper, entitled, "The Collapse of a Building During Con struction," by H. de B. Parsons, M. Am. Soc. C. E., was presentec by the author.

The Secretary presented written communications on the paper fron Messrs. Guy B. Wait, Nathaniel Roberts and C. J. Tilden.

The subject was discussed further by Messrs. F. T. Llewellyn, J. P. Whiskeman, C. C. Schneider, O. Lowinson, H. P. Macdonald and J. H. O'Brien.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

1904.—8.30 P. M.—Vice-President Deyo in the chair; Chas.
nt, Secretary, and present, also, Messrs. Buck, Craven,
, Gowen, Knap, Noble, Osgood, Webster and Wilgus.
n the matter of the appointment of a Special Committee
te and Steel-Concrete" were canvassed, with the following

or of the appointment of the Committee.......	911
st the appointment of the Committee..........	36
Total..	947

ial Committee was appointed.
as taken in regard to members in arrears for dues.
wing Committee was appointed to recommend the award
the year ending with the publications of July, 1904:

Charles L. Strobel,
Samuel Tobias Wagner,
J. L. Ludlow.

the enlargement of the Society House were considered.
ons were considered and other routine business transacted.
e Members were transferred to the grade of Member; one
s transferred to the grade of Associate Member, and six
or Junior were elected.*

d.

*See page 213.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M every day, except Sundays, Fourth of July, Thanksgiving Day an Christmas Day.

MEETINGS.

Wednesday, June 1st, 1904.—8.30 P. M.—A regular busines meeting will be held. Ballots for membership will be canvassed, an a paper, "On Sedimentation," by Allen Hazen, M. Am. Soc. C. E will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, September 7th, 1904.—8.30 P. M.—A regular busines meeting will be held. Ballots for membership will be canvassed, an two papers will be presented for discussion, as follows: "The Instal lation of a Pneumatic Pumping Plant," by Arthur H. Diamant, Jun Am. Soc. C. E., and "Some Notes on the Creeping of Rails," by Sam uel Tobias Wagner, M. Am. Soc. C. E.

Both these papers are printed in this number of *Proceedings.*

ANNUAL CONVENTION, 1904.

The Thirty-sixth Annual Convention will be held at St. Louis, Mo during the week beginning October 3d, 1904.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904.

The Society has undertaken to provide for an engineering exhibit and the establishment of Headquarters for visiting engineers **in th center of the Liberal Arts Building,** and the Board of Direction ha appropriated sufficient funds to defray the necessary expense.

This matter is in the hands of the following Committee:

ROBERT MOORE, M. Am. Soc. C. E., St. Louis, Mo., *Chairman.*
EDWARD C. CARTER, M. Am. Soc. C. E., Chicago, Ill.
MORDECAI T. ENDICOTT, M. Am. Soc. C. E., Washington, D. C.

JAMES L. FRAZIER,	"	"	Frankfort, Ind.
WILLIAM JACKSON,	"	"	Boston, Mass.
EMIL KUICHLING,	"	"	New York, N. Y.
J. L. VAN ORNUM,	"	"	St. Louis, Mo.
JOHN F. WALLACE,	"	"	Chicago, Ill.
O. E. MOGENSEN, *Sec'ty,*	"	"	St. Louis, Mo.

COMMITTEE OF ARRANGEMENTS FOR THE ENTERTAINMENT OF MEMBERS OF THE INSTITUTION OF CIVIL ENGINEERS, IN SEPTEMBER, 1904.

The following committee has been appointed by the Board of Direction to arrange for the reception and entertainment of the members of the Institution of Civil Engineers, who will visit the Society Headquarters in September, 1904:

CHARLES HERMANY, *Chairman*.	ALFRED NOBLE, *Vice-Chairman*.
CHARLES PAINE,	ALLEN HAZEN,
D. J. WHITTEMORE,	RUDOLPH HERING,
THOMAS C. KEEFER,	CLEMENS HERSCHEL,
OCTAVE CHANUTE,	ALEX. C. HUMPHREYS,
MENDES COHEN,	L. M. JOHNSON,
WILLIAM METCALF,	J. J. KENNEDY,
WILLIAM P. CRAIGHILL,	NELSON P. LEWIS,
BENJAMIN M. HARROD,	CHAS. MACDONALD,
DESMOND FITZGERALD,	EDWARD P. NORTH,
JOHN F. WALLACE,	E. E. OLCOTT,
J. JAMES R. CROES,	WM. BARCLAY PARSONS,
ROBERT MOORE,	GEO. H. PEGRAM,
J. A. BENSEL,	SAMUEL REA,
A. P. BOLLER,	JOS. RAMSEY, JR.,
R. S. BUCK,	J. V. W. REYNDERS,
C. W. BUCHHOLZ,	A. A. ROBINSON,
THEODORE COOPER,	W. L. SAUNDERS,
FOSTER CROWELL,	C. C. SCHNEIDER,
S. L. F. DEYO,	J. WALDO SMITH,
G. J. FIEBEGER,	WM. H. WILEY,
G. S. GREENE, JR.,	W. J. WILGUS,
C. E. GRUNSKY,	CHAS. WARREN HUNT, *Secretary*.

As soon as details have been perfected, a circular of information will be issued to the membership.

PRIVILEGES OF LOCAL SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

The **Boston Society of Civil Engineers** will welcome any member of the American Society of Civil Engineers at its library and reading room, 715 Tremont Temple, Boston, which is open on week days from 9 A. M. to 5 P. M. Members will also be welcome at the meetings, which are held in the same building on the evenings of the fourth Wednesday in January, and the third Wednesdays of other months, except July and August.

The rooms of the **St. Louis Engineers' Club**, in the business center of St. Louis, will be kept open during the World's Fair season, May 1st to December 1st, 1904, and visiting engineers are cordially invited to use them for mail, telephone service, information, etc.

The courtesies of the **Engineers' Society of Western Pennsylvania** have been extended to members of the American Society of Civil Engineers. The rooms of the Society, 410 Penn Ave., Pittsburg, Pa. are open at all times, and meetings are held as follows, except during July and August. Regular Section, Third Tuesdays; Chemical Section, Thursdays following third Tuesdays; Mechanical Section first Tuesdays; Structural Section, Fourth Tuesdays.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ACCESSIONS TO THE LIBRARY.

From April 13th to May 10th, 1904.

DONATIONS.*

TABLES SHOWING LOSS OF HEAD DUE TO FRICTION OF WATER IN PIPES.

By Edmund B. Weston, M. Am. Soc. C. E., M. Inst. C. E. Third Edition. Leather, 6 x 4 ins., 5 + 170 pp. New York, D. Van Nostrand Company, 1903. $1.50. (Donated by the author.)

The author states in the preface that, when he first began to make a practical application of hydraulic formulas, he was unable to find one for calculating the loss of head due to the friction of water flowing in pipes, that he had not heard criticised more or less unfavorably. This led him to commence to make special investigations upon the subject. The data of five hundred and twenty experiments, which had been made by twenty-six different investigators, were obtained. A study of these experimental data convinced him that the same formula would not apply to all cases, and that in order to make an intelligent investigation, it would be necessary to divide the data into three classes, viz., those which had been obtained with pipes having very smooth interior sides similar to lead and brass pipes, those with pipes having interior sides similar to new cast-iron pipes, those with pipes having interior sides similar to old cast-iron pipes. The result was the construction by the author of a new formula for the flow of water in pipes having very smooth interior sides, and the conclusion that two formulas constructed by the late Henry Darcy were well adapted for pipes having interior sides similar to new cast-iron pipes. A general formula was not discovered which would apply satisfactorily to old cast iron pipes, but the author has given, in Table No. 2, a series of multipliers which can be used for preliminary work in connection with the table, for very approximately estimating the increase of loss of head due to friction which may take place in pipes that have been in service five or more years.

LANDSCAPE ARCHITECTURE.

Notes and Suggestions on Lawns and Lawn Planting—Laying out and Arrangement of Country Places, Large and Small Parks, Cemetery Plots, and Railway-Station Lawns—Deciduous and Evergreen Trees and Shrubs—The Hardy Border, Bedding Plants—Rockwork, etc. By Samuel Parsons, Jr. Cloth, 9 x 6 ins., 22 + 329 pp., illus. New York, G. P. Putnam's Sons, 1904. $2.00.

The introduction states that the object of this book is to stimulate interest in an inexpensive style of landscape gardening by enunciating a few practical, fundamental principles and to give an account of some examples of well-laid-out grounds and a description of some of the best lawn plants. The chapter headings are: Introduction; The Lawn; The Treatment of Sloping Grounds; Spring Effects on the Lawn; Trees and Shrubs for June Effects on the Lawn; The Flowers and Foliage of Summer; Green Autumnal Foliage; Autumn Color on the Lawn; Lawn-Planting for Winter Effect; Garden Flowers; Grandmother's Garden; Bedding Plants; The Ornamentation of Ponds and Lakes; Lawn Planting for Small Places; City Parks; Railway, Churchyard and Cemetary Lawn-Planting; Nookeries on the Home Grounds; My Friend the Andromeda. There is an index of thirteen pages.

HANDBOOK OF TIMBER PRESERVATION.

By Samuel M. Rowe, M. Am. Soc. C. E. Souvenir Edition, Revised. Leather, 6 x 4 ins., 204 pp., illus. Chicago, Pettibone, Sawtell & Co., 1904. (Donated by the author.)

Since 1885 the author has labored to perfect the methods and appliances, studying each principle and all questions connected with the operation of timber preserving, in the direction of convenience, economy and effectiveness. It is not pretended that the operator can take up the matter from the book and proceed at once to run the business, but the treatise will be of service as a handbook and guide during the operation of the plant as well as in giving hints during the construction. The second edition is published after being revised and extended in its scope. An effort has been made to bring in the writing of other experienced men, as well as to add many items of experience and results of experiments that will aid the student and operator in a fuller understanding of the principles involved in the operation, the nature of the chemicals used, and the character of the woods treated.

* Unless otherwise specified books in this list have been donated by the publishers.

PRACTICAL LESSONS IN ELECTRICITY.

Elements of Electricity; The Electric Current, by L. K. Sager. Electric Wiring, by H. C. Cushing, Jr. Storage Batteries, by F. B. Crocker, M. Am. Inst. E. E. Cloth, 10 x 7 ins., illus. Chicago, American School of Correspondence.

This volume consists of four of the forty-five regular textbooks in the electrical engineering course of the American School of Correspondence at Armour Institute of Technology, bound together in convenient form, but not in the order usually studied. The purpose of the volume is to give the public an opportunity to judge of both the standard and the scope of the instruction offered, the elementary instruction being illustrated by the first half, and the advanced instruction by the last half, of the book. Although published primarily to demonstrate the character of the textbooks of the school, and representing only a fragmentary part of the complete electrical engineering course, yet it is believed that this volume has in itself enough practical information to make it an addition to the library of the expert electrician as well as to that of the amateur.

LES PORTS MARITIMES DE L'AMÉRIQUE DU NORD SUR L'ATLANTIC.

Par Le Baron Quinette de Rochemont et H. Vetillart. Paper, 9½ x 6 ins., Atlas 22 x 15 ins., 3 vol., with Atlas. Paris, Vve. Ch. Dunod, 1898–1904. 65 francs.

Volume I of this work relates to the Canadian ports and Volume II is a study of the administration of navigable ways. Volume III is a monograph on the principal harbors on the eastern coast of the United States: Portland, Sandy-Bay, Boston, New York, Baltimore, Philadelphia, Newport News, Norfolk, Portsmouth, Charleston and Savannah. There is a description of each of these harbors giving its geographical and hydrographical situation, its nautical conditions, the improvements which have been made by the National and State Governments, by local authorities and private enterprise. Statistical information is given which shows the commercial importance, the progress and the customs and taxes received by the public authorities.

LES RÉGULATEURS DES MACHINES À VAPEUR.

Par L. Lecornu. Paper, 12 x 9 ins., 313 pp., illus. Paris, Vve. Ch. Dunod, 1904. 12 francs, 50.

In this work the author has developed, aside from his own theory, the theories of different French and foreign authors, and has compared and discussed them. The book is in two parts: Part. I. Cinématique et Statique du Regulateur; Part II. Dynamique du Régulateur. Part I gives a list of the efforts made to perfect the Watt machine: regulators with centrifugal force, pneumatic, marine, electric, etc. There are many documents on this subject, and the author has brought them all together. The work closes with a treatise on the experiments made to simplify the functions of the regulator. There is an analytical table and an alphabetical index.

Gifts have also been received from the following:

Am. Academy of Arts and Sciences. 7 bound vol., 10 vol.
Am. Gas Light Assoc. 18 bound vol.
Am. Soc. Mech. Engrs. 2 vol.
Asociación de Ingenieros Industriales de Barcelona. 14 vol., 1 no.
Associacao dos Engenheiros Civis Portuguezes. 3 nos.
Atkinson, Edward. 26 pam.
Babcock, J. M. 1 bound vol.
Brackett, Dexter. 1 vol.
Brit. Columbia—Bureau of Provincial Information. 1 bound vol., 4 vol., 6 pam.
Brockton, Mass.—Water Commrs. 1 pam.
Brooklyn, N. Y.—Borough President. 1 bound vol.
Brooklyn, N.Y.—Pub. Lib. 1 vol.
Burlington, Vt.—City Clerk. 1 vol.
Burlington, Vt.—Water Dept. 1 pam.
Buxton, Clifford. 6 vol.
Cal.—Dept. of Highways. 3 pam.
Cambridge, Mass.—City Clerk. 1 bound vol.
Canada—Chf. Engr. of Rys. and Canals. 1 vol.
Canada—Geol. Surv. 1 vol.
Canadian Soc. of Civ. Engrs. 2 pam.
Castellá, Andres. 2 pam.
Church, C. T. 1 pam.
City Record. 1 bound vol.
Civ. Engineers' Club of Cleveland. 1 pam.
Clarkson School of Tech. 1 pam.
Collegio degli Ingegneri ed Architetti in Palermo. 1 vol.
Collegio Toscano degli Ingegneri ed Architetti. 1 bound vol., 21 vol., 9 pam.
Colo.—Commr. of Mines. 1 pam.
Conn.—State Board of Health. 1 bound vol.
Cunningham, A. C. 1 pam.
Delaware Coll. 6 pam.
Eng. Assoc. of the South. 2 vol.
Essex County, N. J.—Park Comm. 4 pam.
Fall River, Mass.—Watuppa Water Board. 2 pam.
Finch, John W. 1 pam.
Fitchburg, Mass.—City Engr. 1 pam.

Great Britain—Patent Office. 4 vol., 5 pam.
Halifax, N. S.—City Engr. 1 pam.
Hunt, Chas. Warren. 1 pam.
Imperial Earthquake Investigation Committee. 1 vol.
Ingenioren. 3 vol., 4 nos.
Inst. of Civ. Engrs. 1 bound vol., 2 vol.
Inst. of Gas Engrs. 1 bound vol.
Iowa—Sec. of State. 1 bound vol.
John Crerar Lib. 1 pam.
Klein, Otto H. 1 bound vol.
Lake Erie & Western R. R. Co. 1 pam.
Lynn, Mass.—Board of Pub. Works. 1 pam.
Madras—Public Works Dept. 1 bound vol.
Me.—Forest Commr. 1 bound vol., 1 vol.
Mass.—Board of Harbor and Land Commrs. 2 bound vol., 14 pam.
Mayne, Charles. 1 vol.
Mazoyer, M. 1 pam.
Medford, Mass.—Water Commrs. 1 pam.
Michigan Central R. R. Co. 1 pam.
Mo.—R. R. & Warehouse Comm. 1 bound vol.
Moberly, Frank. 1 bound vol., 2 pam., 7 maps.
Montreal, Que.—City Surveyor. 18 pam.
National R. R. Co. of Mexico. 1 pam.
N. J.—Commr. of Pub. Roads. 1 pam.
N. Y. City—Commrs. of Accounts. 1 bound vol.
N. Y. State—Dept. of Agri. 3 bound vol.
N. Y. State—Supt. of Forests. 2 vol., 3 pam.
N. Y. State—Supt. of Pub. Bldgs. 3 vol., 1 bound vol.
New York, Chicago & St. Louis R. R. Co. 1 pam.
N. C.—Geol. Surv. 9 vol., 5 pam.
North of England Inst. of Min. and Mech. Engrs. 1 vol.
North-West Ry. Club. 7 vol.
Northern Central Ry. Co. 1 pam.
Norwich Univ. 1 vol.
Nova Scotia—Dept. of Mines. 17 pam.
Ohio—Bureau of Labor Statistics. 3 bound vol.
Peckham, S. F. 1 bound vol.
Penn.—Bureau of Industrial Statistics. 8 bound vol.
Phillips, Hiram. 12 bound vol.
Pinchot, Gifford. 1 pam.
(The) Polytechnic. 5 vol.
Progress Pub. Co. 1 bound vol.
R. I.—R. R. Commr. 1 bound vol.
Rowe, Samuel M. 1 bound vol.
Royal Soc. of Canada. 1 bound vol.
Rutgers Coll. 20 pam.
Salem, Mass.—Water Board. 1 pam.
San Francisco—Board of Supervisors. 1 bound vol.
Sociedad Cientifica "Antonio Alzate." 3 vol., 6 nos.
Société Belge des Ingénieurs et des Industriels. 3 pam.
Société des Ingénieurs Civils de France. 1 vol.
Somerville, Mass.—Board of Health. 11 pam.
Soper, George A. 1 pam.
South Australia—Rys. Commr. 1 pam.
Swarthmore Coll. 1 vol.
Switzerland—Bureau Hydrometic Fédéral. 3 pam.
Taunton, Mass.—Water Commrs. 1 pam.
Tighe, James L. 1 pam.
Umstead, C. H. 2 pam.
U. S. Board on Geographic Names. 1 bound vol., 1 pam.
U. S. Bureau of Construction and Repair. 4 pam.
U. S. Bureau of Fisheries. 7 bound vol., 2 vol.
U. S. Bureau of Forestry. 1 bound vol., 2 vol., 35 pam.
U. S. Bureau of Insular Affairs. 1 pam.
U. S. Bureau of Statistics. 1 bound vol., 2 vol.
U. S. Bureau of Steam Eng. 2 pam.
U. S. Civil Service Comm. 5 bound vol., 1 vol., 2 pam.
U. S. Coast and Geodetic Surv. 2 vol., 6 pam.
U. S. Commr. of Education. 1 bound vol.
U. S. Dept. of Agri. 2 pam.
U. S. Dept. of Labor. 6 bound vol., 2 pam.
U. S. Div. of Foreign Markets. 27 pam.
U. S. Geol. Surv. 9 vol.
U. S. Hydrographic Office. 8 pam.
U. S. Interstate Commerce Comm. 4 pam.
U. S. Naval Academy. 11 pam.
U. S. Naval Inst. 4 vol., 2 nos.
U. S. Ordnance Office. 4 pam.
U. S. War Dept. 15 Specif.
Univ. of Ill. 5 vol.
Univ. of Kans. 24 pam.
Univ. of Mich. 2 pam.
Univ. of Minn. 1 vol., 1 pam.
Univ. of Toronto. 14 vol.
Vt.—State Geol. 1 pam.
Waltham, Mass.—Water Dept. 1 pam.
Wash.—Bureau of Statistics, Agriculture and Immigration. 2 bound vol.
Wash.—State Mine Inspector. 1 vol., 4 pam.
W. Va.—Chief Mine Inspector. 2 vol., 2 pam.
W. Va.—State Geol. 1 bound vol., 1 vol., 1 sheet.
Western Ry. Club. 15 nos.
Western Soc. of Engrs. 1 bound vol.
Weston, Edmund B. 1 bound vol.
Wiley, Wm. H. 1 pam.
Wyo.—State Geol. 1 vol., 5 pam.
Yonkers, N. Y.—Water Commrs. 1 pam.
Unknown. 1 bound vol.

BY PURCHASE.

A Manual of Marine Engineering: Comprising the Design, Construction and Working of Marine Machinery. By A. E. Seaton, M. Inst. C. E., M. Inst. E. E. Fifteenth Edition, thoroughly Revised, Enlarged, and in Part Re-Written. London, Charles Griffin and Company, Limited, 1904.

An Elementary Treatise on Hoisting Machinery, Including the Elements of Crane Construction and Descriptions of the Various Types of Cranes in Use. By Joseph Horner. Philadelphia, J. B. Lippincott Company, London, Crosby Lockwood and Son, 1903.

Traité Théoretique et Practique de Métallurgie Générale. Par L. Babu. Vol. I. Paris, Ch. Beranger, 1904.

Transactions of the American Ceramic Society. Vol. I–II. Columbus, 1900.

Proceedings of the United States Naval Institute. Vol. 5, Nos. 6–7, 10. 1878–79. Annapolis, 1878–79.

The Encyclopedia Americana. A General Dictionary of Arts and Sciences, Literature, History, Biography, Geography, etc., of the World. Vol. 9–11. New York, Chicago, The American Company.

Compendium of Drawing. Compiled from the Instruction Papers in the Mechanical Engineering and Sheet Metal Pattern Drafting Courses of the American School of Correspondence at Armour Institute of Technology. 2 vol. Chicago.

Facts on Fire Prevention. The results of Fire Tests Conducted by the British Fire Prevention Committee. Edited by Edwin O. Sachs. 2 vol. London, B. T. Batsford, 1902.

SUMMARY OF ACCESSIONS.

April 13th to May 10th, 1904.

Donations (including 62 duplicates and 16 numbers completing volumes of periodicals)	662
By purchase	13
Total	675

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
AIMS, WALTON IRVING. Chf. Engr., New York Tunnel Co., 9 East 126th St., New York City		May 4, 1904
ALLEN, WILLIAM BULLARD. Land Agt., Tennessee Coal, Iron & R. R. Co., P. O. Box 873, Birmingham, Ala		Feb. 3, 1904
CARTLIDGE, CHARLES HOPKINS. Bridge Engr., C., B. & Q. R. R., 209 Adams St., Room 61, Chicago, Ill		May 4, 1904
COLLINS, RODERICK GREENE, Jr. Engr. and Gen. Supt., New York Contr. & Trucking Co., 506 East 20th St., New York City		May 4, 1904
DEAN, ARTHUR WARREN. State Engr., State House, Concord, N. H		May 4, 1904
ELLIOTT, JAMES RUTHERFORD. Civ. and Min. Engr. (Elliott & Baton), 1311 Keystone Bldg., Pittsburg, Pa	Assoc. M. M.	Sept. 4, 1901 April 5, 1904
GILLETTE, HALBERT POWERS. Assoc. Editor *Engineering News*, 19th Floor, St. Paul Bldg. (Res., 504 West 151st St.), New York City		May 4, 1904
JACOBS, CHARLES MATTATHIAS. 128 Broadway, New York City.		May 4, 1904
JONES, WILLIAM HENRY. 315 Vine St., Leavenworth, Kans		May 4, 1904
KENLY, EDWARD MARION. Supt., Gorman Coal & Coke Co., Austen, Preston Co., W. Va		May 4, 1904
LOVELL, WALTER DANVILLE. Equitable Bldg., Des Moines, Iowa		May 4, 1904
MACHARG, WILLIAM STORRS. 220 City Hall, Chicago, Ill		Dec. 2, 1903
MACKSEY, HENRY VINCENT. 44 City Hall, Boston, Mass		May 4, 1904
NEWBROUGH, WILLIAM. Civ. and Min. Engr., Evanston, Wyo		April 6, 1904
QUINBY, EDWIN RUFUS. City Surv., 52 Duane St., New York City		May 4, 1904
SNOW, FRANK HERBERT. (Snow & Barbour, Civ. and San. Engrs.), Tremont Bldg., Boston, Mass	Assoc. M. M.	June 4, 1895 May 3, 1904
STONE, EVERETT EDWARD. Asst. Chf. Engr., Boston & Albany R. R., Springfield, Mass		May 4, 1904
STUART, JOSEPH THOMPSON. Engr. of Constr., P. R. R. Co., 1625 North 16th St., Philadelphia, Pa		May 4, 1904
TRETTER, GUSTAV ADOLPH. Asst. Supt. and Engr., Erecting Dept., The Phœnix Bridge Co., Phœnixville, Pa		April 6, 1904
TSUJI, TARO. Engr., Govt. Ry. Office, 24 Hongo Umicho Nichome, Tokyo, Japan	Jun. Assoc. M. M.	Oct. 8, 1891 Oct. 4, 1899 Mar. 1, 1904

		Date of Membership.
WARMAN, FREDERICK CONOVER. U. S. Asst. Engr., 2001 I St., N. W., Washington, D. C.	Assoc. M. M.	Jan. 3, 1900 May 3, 1904
WEBB, WALTER LORING. Cons. Engr., 810 Girard Trust Bldg., Philadelphia, Pa.	Assoc. M. M.	May 4, 1892 May 3, 1904
WOLF, JULIUS HERMAN GEORGE. Asst. Engr., U. S. Engr. Office, 92 Flood Bldg., San Francisco, Cal.	Assoc. M. M.	May 7, 1902 April 5, 1904

ASSOCIATE MEMBERS.

BASSETT, ROBERT JAY. 9816 Ewing Ave., South Chicago, Ill.	Jun. Assoc. M.	Feb. 3, 1903 Feb. 3, 1904
BUTCHER, WILLIAM LARAMY. Asst. Engr., Mass. State Board of Health, 140 State House, Boston, Mass.		May 4, 1904
CLERMONT, JOHN BAPTISTE. Gen. Supt. of Building Constr., 167 Second St., Williamsbridge, New York City		May 4, 1904
COKEFAIR, FRANCIS ALBERTSON. Chf. Engr., Great Northern Power Co., Duluth, Minn.		April 6, 1904
DAVIS, JAMES LYFORD. 7 West 124th St., New York City		May 4, 1904
GALBREATH, WILLIAM OTTO. Care, San Carlos Copper Co., San José, Tamaulipas, Mexico		April 6, 1904
GAYLER, ERNEST ROTTECK. Civ. Engr., U. S. N., Navy Yard, New London, Conn.		April 6, 1904
GIVEN, RICHARD ALEXANDER. 364 Randolph Bldg., Memphis, Tenn.		Feb. 3, 1904
GREENE, ALBERT EMERSON. Asst. Prof. of Civ. Eng., Univ. of Michigan, 415 E. William St., Ann Arbor, Mich.		May 4, 1904
KLOSSOWSKI, THEODORE JULIUS. Care, International Portland Cement Co., Ottawa, Ont., Canada		April 6, 1904
LEFFLER, BURTON RUTHERFORD. 17 Olive Pl., Cleveland, Ohio.		April 6, 1904
LUND, ROBERT LEATHAN. Cons. Engr., Elk Bldg., Little Rock, Ark.		May 4, 1904
REABURN, DEWITT LEE. Care, U. S. Geological Survey, Washington, D. C.		April 6, 1904
UMSTEAD, CHARLES HENRY. Supt. of Constr., U. S. Public Bldgs., Office of the Superv. Archt., U. S. Treasury Dept., Lawrence, Mass.	Assoc. Assoc. M.	May 5, 1903 May 3, 1904
WEST, OSCAR JAMES. Res. Engr., The Phœnix Bridge Co., 453 The Rookery, Chicago, Ill.		May 4, 1904
WILLIAMS, WALTER SCOTT. Asst. Prof. of Civ. Eng., Univ. of Missouri, 906 Conley Ave., Columbia, Mo.		April 6, 1904
WOODARD, WILKIE. City Engr., City Hall, Shreveport, La.		May 4, 1904
WOODS, ANDREW ALFRED, Jr. Res. Engr., A. & V. Ry., Vicksburg, Miss.		May 4, 1904

JUNIORS.	Date of Membership.
GREENLAW, RALPH WELLER. 231 West 125th St., New York City	May 3, 1904
MERRILL, ROBERT HALL. 166 Summer St., Grand Rapids, Mich	May 3, 1904
ROBERTS, HARRY ASHTON. Care, Engr.'s Office, D., L. & W. R. R., Hoboken, N. J	April 5, 1904

CHANGES OF ADDRESS.

MEMBERS.

BAIRD, HOWARD CARTER	Res. Engr. (Boller & Hodge), Dept., Reinforcement and Repairs, Brooklyn Heights R. R. Co., Brooklyn, N. Y.
BALDWIN, HENRY FURLONG	1500 Rodney St., Wilmington, Del.
BEACH, ROBERT JAMES	Pres., R. J. Beach Eng. Co., 32 Broadway, New York City.
BEARD, EDWARD JAMES	Prin. Asst. Engr., C., R. I. & P. Ry. 3838 McGee St., Kansas City, Mo.
BOGART, JOHN	Cons. Engr., 16 Exchange Pl., New York City.
CHAMBERS, FRANK TAYLOR	402 W. Ormsby Ave., Louisville, Ky.
COOPER, THEODORE	Cons. Engr., 45 Broadway, New York City.
COWLES, WALTER LINSLEY	Cons. Engr.; Secy., D. F. Holman Ry. Tracklayer Co., 1749 Railway Exchange, Chicago, Ill.
CREHORE, WILLIAM WILLIAMS	Cons. Engr., on Constr., 116 Nassau St., New York City.
CRUMP, RALPH LEE	Care, Ford, Bacon & Davis, 24 Broad St., New York City.
GRAHAM, JOSEPH MARSHALL	Fourth Vice-Pres., Erie R. R. Co., 21 Cortlandt St., New York City.
HAZLEHURST, GEORGE BLAGDEN	Care, Gen. John Gill, Catonsville, Baltimore Co., Md.
HINCKLEY, JOHN FRANKLIN	Chf. Engr., Frisco System, 800 Fullerton Bldg., St. Louis, Mo.
KEITH, GEORGE THOMAS	Res. Engr., Barge Canal, Fulton, N. Y.
LEFFINGWELL, WILLIAM HOWLAND	Mgr., Divisadero Mine, Divisadero, La Union, Salvador.
LOCKWOOD, JAMES BUTTON CLYDE	Cons. Engr., 661 Worcester Bldg., Portland, Ore.
MINER, CHARLES AUGUSTINE	1007 Adams St., Wilmington, Del.
NETHERCUT, EDGAR S	637 Railway Exchange, Chicago, Ill.
NOBLE, ALFRED	1 West 34th St., New York City.
NORRIS, ROBERT VAN ARSDALE	Bennett Bldg., Wilkesbarre, Pa.

OLMSTED, FRANK HENRY ....Cons. Engr., 1948 Bonsallo Ave., L Angeles, Cal.

PERKINS, EDMUND TAYLOR......... Care, U. S. Geological Survey, 1108 Bra Bldg., Los Angeles, Cal.

PURDON, CHARLES DE LA CHEROIS....Engr., M. of W., Frisco System, S Louis, Mo.

READ, ROBERT LELAND ....68 Summer St., Malden, Mass.

SCOTT, ERNEST KAY ....Care, Hoover & Mason, 1407 Railway E change, Chicago, Ill.

STERN, EUGENE WASHINGTON........Cons. Engr., 7 West 38th St., New Yo City.

TUCKER, LESTER WALDO............Asst. Engr., Del. & Hudson R. R., 216 S Center St., Schenectady, N. Y.

VERRILL, GEORGE ELLIOT..........Supt., U. S. Engr. Dept., 865 Chap St. (Res., 341 Winthrop Ave.), Ne Haven, Conn.

WEBSTER, CHARLES EDWARD........Cons. Engr., South Bethlehem, Pa.

WILLIAMSON, SYDNEY BACON........With Expanded Metal Eng. Co., 2 Broadway, New York City.

WATSON, WILLIAM PARSONS ....Eng. Dept , U. P. R. R., Omaha, Nebr.

ASSOCIATE MEMBERS.

ARCHER, STEVENSON, Jr.............Greenville, Miss.

BAKER, ELISHA BROWN..............Pres., Baker Contract Co., 1305 Farme Bank Bldg., Pittsburg, Pa.

BERGER, BERNT.....................Asst. to Theodore Cooper, 45 Broadwa New York City.

COLE, HERBERT NICHOLS............Care, Semet-Solvay Co., Milwaukee, Wi

EDER, HENRY JAMES.............. .Cali, Colombia.

FOX, WALTER GORDON..............65 West 48th St., New York City.

GILLESPIE, RICHARD HENWOOD......Asst. Engr. Bureau of Highways, Bron (Res., 2774 Briggs Ave., Bedford Park New York City.

GROSS, DANIEL WINGERD............Queens Run Fire Brick Co., Lock Have Pa.

HAYS, DON ....207 W. Illinois St., Urbana, Ill.

HERRING, WILLARD E...............714 East 9th St., Kansas City, Mo.

MACY, ELBERT CLYDE...............Prin. Asst. Engr., C. G. W. Ry., St. Pau Minn.

MORRISON, EUGENE TAYLOR.........Asst. Engr., Bridge and Constr. Dept Penn. Steel Co., Steelton, Pa.

MORISON, WILLIAM SMITH..........1515 Franklin St., Wilmington, Del.

NICHOLS, CLARENCE HICKS...... ...36 West 37th St., New York City.

PARSONS, ARCHIBALD LIVINGSTONE...Civ. Engr., U. S. N., Cavite, Philippin Islands.

PATERSON, HARRY THOMAS ....Asst. Engr., U. S. Geological Surve Cody, Wyo.

PHILLIPS, THEODORE CLIFFORD .....Civ. and Hydr. Engr., Care, Edw. S. Cole, 220 Broadway, New York City.
PRITCHETT, CHARLES MARCELLUS....Care, J. E. Sirrine, Greenville, S. C.
SEUROT, PAUL ALBERT............. Office Engr., North River Div., Penn., N. Y. & L. I. R. R. Co., 1 West 34th St., New York City.
SKELLY, JAMES WILLIAM............Junior Engr., U. S. Engr. Depot, Foot of Arsenal St., St. Louis, Mo.
SLAYTON, CHARLES ALBERT ....St. L., Brownsville & Mex. Ry., Corpus Christi, Tex.
THOMSON, ERNEST BURSLEM.........U. S. Asst. Engr., U. S. Engr. Office, Miami, Fla.
WILLIAMS, CHARLES PAGE ....Ft. Michie, N. Y., via New London, Conn.
WILLIAMS, SAMUEL DAUGHERTY, JR .513 Nasby Bldg., Toledo, Ohio.

ASSOCIATES.

DEWEY, CHARLES ELLIS............46 Bank Bldg., Watertown, N. Y.

JUNIORS.

BENTON, LEWIS STEUERWALD........Office of 2d Asst. Engr., L. S. & M. S. Ry., Cleveland, Ohio.
CLEAVER, PITSON JAY........... ...Fort Edward, N. Y.
DAVIES, WILLIAM GOMER...........Care, U. S. Geological Survey, St. Anthony, Idaho.
EDWARDS, OLIVER CROMWELL, Jr....Box 163, Mingo Junction, Ohio.
FISCHER, GUILLERMO GUSTAVO.......Trinidad, Provincia de Santa Clara, Cuba.
HARPS, HARRY MACY. .... Nantucket, Mass.
HARRIS, HENRY ALEXANDER.........New Hope, Pa.
HARSHBARGER, ELMER DWIGHT......Aspinwall, Pa.
HOWES, RALPH HOLT...............Civ. Engr., Wells Bros. Co. of New York, 400 Oak St., Syracuse, N. Y.
MINER, JAMES HENRY...............Care, Prairie Oil & Gas Co., Neodesha, Kans.
PEARSE, LANGDON ....317 Walnut Ave., Roxbury, Mass.
SACKETT, ARTHUR JOHNSON..........Care, U. S. Engr. Office, Miami, Fla.
SCOTT, GUY.......................Asst. Engr., Penn. Co., Box 331, Wellsville, Ohio.
SUSSEX, JAMES WOLFE .... Abingdon, Ill.
TAYLOR, HOWARD FLANDERS . . ...800 Brighton Ave., Kansas City, Mo.
UNDERWOOD, HOWARD WARREN .... Asst. Engr., Bureau of Filtration, Pittsburg, Pa.
WENIGE, ARTHUR EMIL........... .Care, Bureau of Sewers, Room 44, Municipal Dept. Bldg., Brooklyn, N. Y.
WHITTED, LEVI ROMULUS...........Supt. of Constr., U. S. Public Bldgs., Rome, Ga.
WOODCOCK, HENRY WRIGHT.........361 Ocean Ave., Brooklyn, N. Y.

DEATHS.

AINSLEE, JAMES W. . . . . .Elected Fellow, May 28th, 1872; September 13th, 1902.

AINSWORTH, DANFORTH HURLBUT. . . .Elected Member, March 3d, 1886; April 24th, 1904.

RICHARDSON, B. FRANK . . . . .Elected Member, July 1st, 1885; April 18, 1904.

STORROW, CHARLES STORER . . . . .Elected Honorary Member, January 18:3; died April 30th, 1904.

HLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(April 14th to May 10th, 1904.)

—This list is published for the purpose of placing before the members ety the titles of current engineering articles, which can be referred vailable engineering library, or can be procured by addressing ation directly, the address and price being given wherever

LIST OF PUBLICATIONS.

ubjoined list of articles references are given by the number pre- h journal in this list.

l, Assoc. Eng. Soc., 257 South th St., Philadelphia, Pa., 30c.
dings, Engrs. Club of Phila., Girard St., Philadelphia, Pa.
l, Franklin Inst., Philadel- , Pa., 50c.
l, Western Soc. of Engrs., Mo- ock Block, Chicago, Ill.
ctions, Can. Soc. C. E., Mon- , Que., Canada.
of Mines Quarterly, Columbia ., New York City, 50c.
logy Quarterly, Mass. Inst. ., Boston, Mass., 75c.
Institute Indicator, Stevens , Hoboken, N. J., 50c.
eering Magazine, New York , 25c.
's Magazine, New York City,
eering (London), W. H. Wiley, York City, 25c.
gineer (London), International s Co., New York City, 35c.
ering News, New York City,
ngineering Record, New York , 12c.
ad Gazette, New York City,
eering and Mining Journal, York City, 15c.
Railway Journal, New York , 35c.
y and Engineering Review, ago, Ill., 10c.
fic American Supplement, New City, 10c.
ge, New York City, 10c.
y Engineer, London, Eng- , 25c.
d Coal Trades Review, Lon- England, 25c.
n, American Iron and Steel c., Philadelphia, Pa.
an Gas Light Journal, New City, 10c.
an Engineer, New York City,
cal Review, London, England.
cal World and Engineer, New City, 10c.
l, New England Water-Works c., Boston, $1.
al, Society of Arts, London, land, 15c.
es des Travaux Publics de ique, Brussels, Belgium.
s de l' Assoc. des Ing. Sortis École Spéciales de Gand, Brus- Belgium.
ires et Compte Rendu des Tra- , Soc. Ing. Civ. de France, s, France.

(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(69) *Mill Owners*, New York City, 10c.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs. London, England.

LIST OF ARTICLES.

Bridge.

Recent Road-Bridge Practice in New South Wales.* Henry Harvey Dare, Assoc. M. Inst. C. E. (63) Vol. 155.
The Value of Inspection of Metal Bridges During Construction and Erection. Walter L. Golden. (Paper read before the Engineers' Soc. of Western New York.) (1) Mar.
Construction of a Scherzer Double-Roller Lift Bridge at Middle Seneca Street, Cleveland, Ohio.* William J. Carter. (Paper read before the Civ. Engineers' Club of Cleveland.) (1) Mar.
Some Points in Bridge Design: Effect on Trusses and Plate Girders Due to Imperfect Roller-Support.* Geo. N. Linday. (4) Apr.
The Elizabeth Bridge, Budapest.* (12) Serial beginning Apr. 15.
A Long-Span Double-Track Plate-Girder Bridge.* (14) Apr. 16.
The Erection of the Clairton Bridge.* (14) Apr. 16.
The Design of Concrete Steel Arches. E. J. McCaustland. (Paper read before the Amer. Assoc. for the Advancement of Science.) (13) Apr. 21.
Erecting Bridge Spans by Sliding Them Forward from the Shore.* (13) Apr. 21.
Highway Bridges in the Croton Valley.* (14) Apr. 23.
Replacing a Lattice-Girder Bridge with Plate Girders.* (14) Apr. 23.
Concrete Railway Bridges.* (46) Apr. 23.
New Counterbalanced Swing Bridge, C., M. & St. P. Ry.* (18) Apr. 28.
Masonry for the Blackwell's Island Bridge.* (15) Apr. 29.
The Fraser River Bridge, British Columbia.* (14) Serial beginning Apr. 30.
The Harway Avenue Bascule Bridge, New York City.* (14) Apr. 30.
Interlocking Steel Sheet Piles for Bridge Pier Cofferdams.* (14) Apr. 30.
Test to Destruction of a 65-ft. Truss Bridge Span of Reinforced Concrete.* (13) May 5.
A Large Plate Girder Bridge on the Erie.* (15) May 6.
La Chaine avec l'Arc.* M. Legay. (43) 4e Trimestre, 1908.
Un Tracé Géométrique des Paraboles Cubiques et Ses Applications aux Lignes d'Influence dans les Poutres Continues.* Farid Boulad. (43) 4e Trimestre, 1908.
Note sur l'Approximation des Formules de Flexion des Arcs.* M. Mesnager. (43) 4e Trimestre, 1908.
Essai à Outrance du Pont d'Ivry.* M. Considère. (43) 3e Trimestre, 1908.
Notice sur un Pont en Béton Armé, Système Hennebique, Construit sur l'Aisne, à Soissons.* M. Riboud. (43) 3e Trimestre, 1908.
Note sur la Construction du Viaduc des Fades (Ligne de Saint-Éloy à Pauniat).* M. Virard. (43) 3e Trimestre, 1908.
Ponts Roulants à Bascule, Système Scherzer: Pont de Barking (Angleterre).* (33) Apr. 2.

Electrical.

Line Effects in Long-Distance Transmission of Power by Electricity. Henry James Shedlock Heather, Assoc. M. Inst. C. E. (63) Vol. 155.
Better Electric Insulation. C. E. Farrington. (69) Mar.
Gas Power for Central Stations. J. R. Bibbins. (42) Mar.
The Conductivity of the Atmosphere at High Voltages.* Harris J. Ryan. (42) Mar.
European Practice in the Construction and Operation of High-Pressure Transmission Lines and Insulators.* Guido Semenza. (42) Mar.
Notes on Fly-Wheels (for reciprocating engines direct connected to alternators). H. H. Barnes, Jr. (42) Mar.
Distorted Alternating and Rotating Magnetic Fields. R. Goldschmidt. (26) Serial beginning Apr. 8.
The New Electricity Works and Tramways of West Ham.* (26) Apr. 8.
The Adaptability of Electrical Driving. B. Longbottom. (Abstract of paper read before the Manchester Assoc. of Engrs.) (73) Apr. 8; (47) Apr. 16.
Single-Phase Motors.* (73) Serial beginning Apr. 8.
Notes on Impedance Coils.* C. Faraday Proctor. (Abstract of Paper read before the Inst. E. E.) (73) Apr. 8.
Design of Small Dynamos.* J. W. Burleigh. (26) Apr. 8.
Electric Conduit Construction at Memphis, Tenn.* F. G. Proutt. (13) Apr. 14.
Aston Manor Electricity Works.* (26) Apr. 15.
Small Gas Engines v. Electric Motors. H. E. M. Kensit. (26) Apr. 15.
150-Horse-Power Compound Electric-Light Engines for the Royal Navy.* (11) Apr. 15.
Eddy Currents in Cable Sheaths. M. B. Field. (Paper read before the Inst. E. E.) (73) Serial beginning Apr. 15.
Localisation of Faults on Low-Tension Networks. W. E. Groves. (Abstract of Paper read before the Inst. E. E.) (73) Apr. 15; (26) Serial beginning Apr. 8.
Experiments with a New Primary Cell. Geo. P. Bousfield. (Paper read before the Faraday Soc.) (73) Apr. 15.
A General Diagram for Alternators. (73) Apr. 15.
A Long-Span Transmission Line.* B. Wiley. (27) Apr. 16.
The Efficiency Curves of Constant-Potential Transformers. A. E. Kennelly. (27) Apr. 16.

---

*Illustrated.

Electrical—(Continued).

Theoretical Determination of Power Curves. (27) Apr. 16.
Design of Continuous-Current Motors for Variable Speed. Franklin Punga. (26) Apr. 22.
Sunderland Corporation New Electricity Works.* (26) Apr. 22.
Dynamo and Motor Testing. C. F. Smith. (Abstract of Paper read before the Civ. and Mech. Engineers' Soc.) (26) Serial beginning Apr. 22.
Theoretical Basis for the Experimental Pre-Determination of the Regulation of Alternators. Theo. Torda-Heymann. (73) Apr. 22.
Methods for Increasing the Transmitter Energy of Wireless Telegraph Systems.* Ferdinand Braun. (73) Apr. 22.
Notes on the Design of Electrical Machinery. Louis J. Hunt, Assoc. M. Inst. C. E. (Paper read before the Liverpool Eng. Soc.) (47) Serial beginning Apr. 23; Abstract (73) Apr. 29.
The Atlanta Water & Electric Power Company's Plant at Morgan Falls.* (14) Apr. 23.
The New Telephone Exchange of Berlin.* Emile Guarini. (19) Apr. 23.
The Hospitalier Ondograph.* (19) Apr. 23.
Electric Distribution to Small Manufactories at Sant Mortier, France.* Franz Koster. (27) Apr. 23.
The Elementary Principles of Transformer Design. Thomas Gray. (27) Serial beginning Apr. 23.
The Prevention of Crosses between Signalling and High Voltage Circuits.* Howard S. Knowlton. (27) Apr. 23.
A New Push-Button Voltmeter Switch.* Charles L. Fitch. (27) Apr. 23.
100-Ton Double Trolley Alternating Current Crane.* W. W. Briggs. (27) Apr. 23.
The Measurement of Electrical Conductivity.* J. Rymer-Jones. (26) Serial beginning Apr. 29.
Electric Governing of Steam Turbines.* (From the *Western Electrician* of Chicago.) (73) Apr. 29.
Power Station Design.* C. H. Merz and Wm. McLellan. (Abstract of Paper read before the Inst. E. E.) (73) Serial beginning Apr. 29.
The Power Plant and Electric Railway Owned by the State of North Dakota.* (17) Apr. 30.
Electrolytic Rectifiers for Charging Storage Batteries with Alternating Current. Charles F. Burgess. (Paper read before the Northwestern Elec. Assoc.) (19) Apr. 30.
The Plant of the Kansas City Home Telephone Company.* Max Loewenthal. (27) Apr. 30.
The Design of Induction Motors with Examples from Recent European Practice. H. M. Hobart. (27) Apr. 30.
The Braun Tube in the Study of Alternating Currents. (27) Apr. 30.
Construction of a 2-H. P. Direct-Current Motor.* F. C. Mason. (From *Amer. Electrician.*) (47) Apr. 30.
A Test for Induction Motor Windings.* G. H. Garcelon. (From *Elec. Club Journal.*) (47) Apr. 30.
Tullahoma, Tenn., Water and Light Plant. Granbery Jackson. (60) May.
Some Electric Furnace Processes.* J. Wright. (10) May.
Practical Applications of Electro-Magnets in the Modern Machine Shop, Iron and Steel Works and Shipyard.* Frank C. Perkins. (41) May.
Experiments with Three-Phase Electric Arcs.* (46) May 7.
1 500-K. W. Alternator for St. Louis.* (17) May 7.
The Snoqualmie Falls and White River Power Developments.* (27) May 7.
Electricity at the St. Louis Exposition, 1904.* (27) May 7.
A Convenient and Economical Electrical Method for Determining Mechanical Torque.* A. S. McAllister. (27) May 7.
Central Station Economy. F. H. Davies. (From *Elec. Engr.*) (24) Serial beginning May 9.
Électro-Aimants Industriels à Longue Course et à Efforts Variables.* R. Bérard. (32) Feb.
Les Progrès de la Télégraphie sans Fil.* (33) Apr. 2.
Lur la Mesure de la Puissance des Courants Triphasés.* Maurice Soubrier. (36 Apr. 25.
Sur les Diagrammes de Fonctionnement d'un Alternateur.* C. F. Guilbert. (36) Serial beginning Apr. 25.
La Telephone sans Fil au Moyen des Piles a Sélénium.* Alfred Gradenwitz. (36) Serial beginning Apr. 25.

Marine.

A New Japanese Battleship.* (12) Apr. 8.
Steam Turbine Propulsion for Marine Purposes.* A. Rateau. (Abstract of Paper read before the Inst. of Naval Archts.) (12) Apr. 8; (11) Apr. 8.
Engineering in the Japanese Navy.* Miyabara. (Paper read before the Japanese Soc. of Naval Archts.) (11) Apr. 15.
The Normal Pressures on Thin Moving Plates. A. W. Johns. (Abstract of Paper read before the Inst. of Naval Archts.) (12) Apr. 15.
The Problem of Screw Propulsion. Arthur Rigg. (12) Serial beginning Apr. 15.

*Illustrated.

Marine—(Continued).

A New Invention for Rendering Vessels Unsinkable.* Herbert C. Fyfe. (19) Apr. 16.
Automatic Governing of Marine Engines.* H. M. Wilson. (Paper read before the Northeast Coast Inst. of Engrs. and Shipbuilders.) (47) Apr. 16.
The Transverse Strength of Ships.* J. Bruhn. (Paper read before the Inst. of Naval Archts.) (11) Apr. 22.
The Management of Belleville Boilers at Sea. E. F. Baker. (Paper read before the North-east Coast Inst. of Engrs. and Shipbuilders.) (11) Apr. 29.

Mechanical.

The Manufacture of Welded Pipe.* Victor Beutner. (58) Jan.
The De Laval Steam Turbine.* Charles Garrison. (7) Mar.
A Standard Unit of Refrigeration. J. C. Bertsch. (69) Mar.
The Use of Pulverized Coal for Fuel under Steam Boilers.* J. M. Sweeney. (4) Apr.
Notes on Burning Bituminous Coal. John M. Hartman. (2) Apr.
New Steam Turbine Developments.* W. L. R. Emmet. (2) Apr.
Mechanical Refrigeration of Freight Cars.* Warren H. Miller. (8) Apr.
Furnace Charging Cranes.* (22) Apr. 1.
Allen's High-Speed Triple Expansion Engine.* (22) Apr. 1.
A Few Notes on the Steam Turbine. G. L. Parsons. (Abstract of Paper read before the Inst. E. E.) (73) Apr. 8.
Defects in Cast Iron: Their Causes and Remedies. Herbert E. Field. (Paper read before the New England Foundrymen's Assoc.) (47) Apr. 9.
The Design of Machinery Shafting.* C. F. Blake. (47) Apr. 9.
Friction Clutches on Automobiles.* (47) Serial beninning Apr. 9.
Berg Motor Fluid Generator.* Rudolf Berg. (62) Apr. 14.
A Slot Milling Machine.* (40) Apr. 14.
The Blaisdell Tandem Gas Engine.* (40) Apr. 14.
The Crandall Mechanical Lubricating System.* (40) Apr. 14.
High Speed Tool Steels. Wm. Lodge. (Abstract of Paper read before the National Metal Trades Assoc.) (15) Apr. 15.
The Practical Management of Stationary Steam Boilers.* R. T. Cooke, M. I. Mech. E. (12) Apr. 15.
Liquid Fuel Burners.* J. S. V. Bickford. (11) Serial beginning Apr. 15.
The Equipment of an Engine Test-House. R. K. Morcom, Assoc. M. I. E. E. (Paper read before the Inst. E. E.) (12) Apr. 15; (11) Apr. 22; (47) Apr. 23.
The Mechanical Plant of the Minnesota State Capitol.* (14) Apr. 16.
The Utilisation of Blast Furnace Slag.* E. R. Sutcliffe. (Abstract of Paper before the West of Scotland Iron and Steel Inst.) (22) Apr. 15. (62) Serial beginning May 5.
A Compound Gasolene Engine.* (14) Apr. 16.
Teeth in Gearing.* Samuel Diescher. (62) Apr. 21.
Bagging in Clean Boilers, and the Repulsion Theory. D. B. Dixon. (62) Apr. 21.
Reamer Clearances.* Fred Holz. (20) Apr. 21.
The Yale & Towne Mfg. Company's Power Plant.* (20) Apr 21.
Popular Motor Cars. Mervyn O'Gorman, M. I. E. E. (29) Apr. 22.
High-Speed Tool Steel, Its Manufacture and Uses.* J. M. Gledhill. (Abstract of Paper read before the Coventry Eng. Soc.) (22) Apr. 22.
Horse Power of Steam Engines. Irving A. Taylor. (27) Apr. 23.
A New English Aluminium Welding Machine.* Frank C. Perkins. (46) Apr. 23.
Chimneys. Chas. L. Hubbard. (47) Apr. 23.
The Steam Turbine as an Exhaust Steam Utilizer. (14) Apr. 23.
Type-Composing and Distributing Machines.* (12) Apr. 29.
The Cooling of Explosion Motors on Automobiles.* J. Grouvelle and H. Arquembourg. (Paper presented to Second International Automobile Cong.) (47) Apr. 30.
Rope Transmission in Textile Mills. (14) Apr. 30; (20) May 5.
Engineering Problems in Tanneries.* (14) Apr. 30.
The Fenimore Sulphite Mill.* (14) Apr. 30.
The Inclined Elevator at Weehawken, New Jersey.* (14) Apr. 30.
Trials of Rock Drills for Air Consumption. J. B. Carper, E. Goffe, and W. C. Docharty. (68) Serial beginning Apr. 30.
Boiler Design and Boiler Explosions. R. S. Hale. (9) May.
Hydraulic Cranes and Wharf Machinery.* George H. Baxter. (9) May.
Fuel Economy in Steam Plants. John B. C. Kershaw. (10) May.
Power Plant of the Yale & Towne Manufacturing Company.* (64) May.
Test of the Engines of the Rochester Gas and Electric Company.* (64) May.
New Westinghouse Turbine.* (64) May.
The Care and Management of Leather Belts.* Walter E. Dixon. (64) May.
Some Causes and Remedies for Pounding in Engines.* W. E. Crane. (64) May.
Indicator Spring Errors. H. Boyd Brydon. (64) May.
Setting Up a Vertical Engine. John F. Nagle. (64) May.
Multiple Impact Steam Turbine.* A. M. Levin. (64) May.
Lubricating Oils and Their Properties.* Wm. Davis. (64) May.
Burning Coke Breeze with Underfeed Stokers. M. E. Malone. (Paper read before the Ohio Gas Light Assoc.) (24) May 2.
Burning Coke Breeze on Hollow Grates. C. H. Williams. (Paper read before the Ohio Gas Light Assoc.) (24) May 2.

---

*Illustrated.

Mechanical—(Continued).

A New Spanish Portland Cement Works.* (13) May 5.
The New Merriman Automatic Bolt Cutter.* (20) May 5.
Modern Methods of Handling Iron Ore from Minnesota Mines to Pittsburg Furnaces.* Charles H. Wright, M. Am. Soc. C. E. (13) May 5.
Rock-Drill Bits.* T. H. Proske. (16) May 5.
The De Brouwer Mechanical Stoker.* (19) May 7.
The Effect of Pressures on the De Laval Steam Turbine. (14) May 7.
Alcohol for Internal Combustion Engines. (14) May 7.
Laying Gas Mains across a River. H. C. Morris. (Abstract of Paper read before the Mich. Gas. Assoc.) (14) May 7.
Deux Appareils Nouveaux pour la Mesure des Déformations Élastiques.* M. Mesnager. (43) 3e Trimestre, 1903.
Le Train Automobile du Colonel Renard.* A. Debauve. (43) 4e Trimestre, 1903.
Pompe Centrifuge à Haute Pression: Système de Laval.* K. Sosnowski. (32) Feb.
Étude sur le Moulage Mécanique.* P. Avaurieu. (37) Serial beginning May 31.
Construction des Hélices Transporteuses.* (34) Apr.
Générateur de Vapeur à Tubes d'Eau, avec Surchauffeur de Vapeur. G. Bailly-Mathot. (34) Apr.
Distribution de Vapeur à Soupapes et à Déclic: Système Proell. (34) Apr.
La Manutention Mécanique dans l'Atelier de Distillation d'une Usine à Gaz.* M. A. Thibeault. (33) Serial beginning Apr. 16.
Puissance Absorbée pour le Perçage des Métaux. (33) Apr. 23.
L'Etirage à Cylindres Étireurs Lisses a Cylindres de Pression Garnis de Drap et Cuir, Commandés par Pignons Fous sur les Axes de Ces Cylindres de Pression, de F. Ter Weele.* A. J. Ernst. (36) Apr. 25.
Étude sur la Motocyclette.* H. de Graffigny. (36) Serial beginning Apr. 25.
Étude sur les Embrayages Appliques a l'Automobilisme et sur les Types Nouveaux Exposés au Salon de 1903. E. André. (36) Serial beginning Apr. 25.

Metallurgical.

The Applications of Electricity to Metallurgy. Joseph W. Richards. (7) Mar.
Stock Distribution and Its Relation to the Life of a Blast Furnace Lining.* David Baker. (22) Apr. 8.
Fan Power for the Cupola. Thos. D. West. (Paper read before the Pittsburg Foundrymen's Assoc.) (47) Apr. 9.
The Calculation of the Value of the Raw Material in Pig Iron Making. A. P. Gaines. (40) Apr. 14.
Filter Pressing in Western Australia.* W. A. Prichard. (16) Apr. 14.
The Relation of Microstructure to the Rate of Cooling.* W. Campbell. (Lecture to the Phil. Foundrymen's Assoc.) (20) Apr. 21.
Magnetic Ore Dressing on the Wetherill System.* Heinrich Ostwald. (Tr. from *Berg- und Hüttenmännische Zeitung.*) (68) Serial beginning Apr. 23.
Slime Treatment in the Joplin Region.* W. R. Crane. (16) Apr. 28.
Zinc in the Blast Furnace. John J. Porter. (62) Apr. 28.
The Hendryx Cyanide Process.* C. M. Fassett. (16) May 5.
Segregation and Diffusion in Steel. B. F. Weston. (62) May 5.
Furnace Top Explosions. Frank C. Roberts. (20) May 5.
Nitrogen in Iron and Steel.* Ernst A. Sjöstedt. (20) May 5.
Electrolytic Iron. C. F. Burgess and Carl Hambuechen. (19) May 7.
La Cémentation des Aciers au Carbone & des Aciers Spéciaux.* Léon Guillet. (32) Feb.
Calcul des Lits de Fusion des Hauts Fourneaux par la Méthode de Platz. (33) Apr. 9.

Military.

High-Velocity 6-inch Wire-Wound Gun for the United States Army.* (46) May 7.

Mining.

Electric Installation at the Noel-Sart-Culpart Collieries, Belgium.* (22) Apr. 8.
Sinking a Shaft 4,662 Feet Deep.* (22) Apr. 8.
Electric Winding Engines.* Maurice Georgi. (Paper read before the Inst. E. E.) (47) Apr. 9.
The Sirocco Fan.* (16) Apr. 14.
Explosions in Air Compressors. E. Goffe. (Paper read before the Mech. Engineers' Assoc. of the Witwatersrand.) (47) Apr. 16; Abstract (16) Apr. 28; (22) Apr. 22.
Electric Winding Engines. (22) Apr. 15.
Electric Power Applied to Winding in Main Shafts.* W. C. Mountain. (Abstract of Paper read before the Inst. of Min. Engrs.) (68) Apr. 16.
The Development of the Electric Mining Locomotive.* Frank C. Perkins. (19) Serial beginning Apr. 23.
Mine Haulage Systems. T. G. Altman. (45) May.
Coals and Coal-Mining Methods of the Pocahontas Field.* Geo. L. Fowler. (9) May.
Water Hoisting instead of Pumping.* R. V. Norris. (10) May.
The Ernest Plant of the Jefferson & Clearfield Coal & Iron Co., at Ernest, Indiana County, Pennsylvania.* G. W. Harris. (45) May.
Gases in Metalliferous Mines. Harry A. Lee. (Abstract.) (45) May.

*Illustrated.

Mining—(Continued).

Whipple Colliery.* (45) May.
The Auchincloss Colliery.* (16) May 5.
The Support of Excavations in the Witwatersrand Mines.* T. Lane Carter. (16) May 5.

Miscellaneous.

On the Distribution of Mean and Extreme Annual Rainfall over the British Isles. Hugh Robert Mill. (63) Vol. 155.
The Engineering Characteristics of St. Louis, U. S. A.* (12) Serial beginning Apr. 22.
The Yerkes Observatory.* (11) Serial beginning Apr. 29.
A Radial Area-Scale.* R. W. K. Edwards. (Paper read before the Royal Soc.) (68) Apr. 30.
The Building of a World's Fair.* (14) May 7.

Municipal.

Automobile Fire Engines.* Emile Guarini. (19) Apr. 16.
Specifications for Asphalt Pavements. (60) May.

Railroad.

Copper Locomotive-Boiler Tubes. Francis William Webb. (63) Vol. 155.
The Lackawanna and Wyoming Valley Railroad.* George B. Francis. (Paper read before the Boston Soc. of Civ. Engrs.) (1) Mar.
Steel in Car Construction. C. A. Seley. (61) Mar. 15.
Eight-Coupled Tank Locomotive for New South Wales.* (11) Apr. 8.
Reinforced Concrete Roof for a Locomotive Roundhouse, Long Island R. R.* (13) Apr. 14.
Practice in Re-Establishing and Monumenting a Railway Center Line. Albert I. Frye, M. Am. Soc. C. E. (13) Apr. 14.
Heavy Tank Engines with Three Cylinders, Berlin Metropolitan Railway.* (12) Apr. 15.
Oblique Type Crank Axles.* (12) Apr. 15.
Smoke-Box Action. R. Weatherburn. (12) Apr. 15.
The Fairview Yard, Northern Central and P. R. R.* (15) Apr. 15.
Developments in Heavy Electric Traction. C. L. de Muralt. (15) Apr. 15.
The Schenectady Improvements of the New York Central.* (15) Apr. 15.
Eight-Coupled Freight Locomotive: Lancashire & Yorkshire. (15) Apr. 15.
Locomotive Injector Troubles and Repairs.* Fred. H. Colvin. (47) Apr. 16.
New Shops of the Terminal Railroad Association of St. Louis.* (18) Apr. 16.
Michigan Central Pacific Type Locomotive.* (18) Apr. 16.
The Southern Missouri Railway.* Charles A. Sheppard. (14) Apr. 16.
Experience with Skylight Construction for Railway Train Sheds. (13) Apr. 21.
Lancashire and Yorkshire Railway: Bolton New Station.* (26) Apr. 22.
Electric Interlocking at the New Central Station in Antwerp.* L. Weissenbruch. (40) Serial beginning Apr. 22.
Petrol Electric Coach on the N. E. R.* (12) Apr. 22; (11) Apr. 22.
All-Electric Interlocking at Park Junction.* (15) Apr. 22.
Westinghouse No. 85 Railway Motor.* (17) Apr. 23.
A New System of Current Collecting for Heavy Electric Traction Lines.* Henri Somach. (17) Apr. 23.
Driving a Test Pile for the Hudson River Tunnel.* (46) Apr. 23.
Track Construction with Steel Longitudinals.* (13) Apr. 28.
Momentum Grades: Some Comments on Their Literature and Their Probable Future Use. W. D. Taylor, M. Am. Soc. C. E. (13) Apr. 28.
The Hottman Water Tube Locomotive Boiler.* (20) Apr. 28.
New Rolling Stock for the Rhodesia Railways.* (12) Apr. 29.
New York Central Four-Cylinder Balanced Compound.* (40) Apr. 29.
Pacific Type (4-6-2) Locomotive for the Michigan Central * (15) Apr. 29.
Electric Auto Cars—North Eastern Railway. (15) Apr. 29.
The Los Angeles & Redondo Railway.* (17) Apr. 30.
A German High-Speed Locomotive.* (46) Apr. 30.
Side-Door Steel Suburban Cars for the Illinois Central Railroad.* (17) Apr. 30.
Large Modern Coaling Station of the Terminal Railroad Association of St. Louis.* (18) Apr. 30.
An Interesting Design of Locomotive Boiler. (39) May.
Standard Front End Arrangement, G. S. & F. Ry.* (39) May.
Driving Wheel Drop Table—Southern Railway.* (39) May.
New Type of Canvas Diaphragm.* (39) May.
The Manufacture of Hydraulically Forged and Rolled Solid Steel Railway Wheels. Henrik V. von Z. Loss, M. Am. Soc. M. E. (3) May.
Special Machine Tools for Locomotive Shops.* Joseph Horner. (10) May.
Cole's 4-Cylinder Balanced Compound Locomotive: New York Central & Hudson River Railroad: 4-4-2 Type.* (25) May.
The Largest of Locomotive Boilers: for Mallet-Compound Locomotive: Baltimore & Ohio R. R.* (25) May.
Some Details of a Very Heavy Locomotive: Atchison, Topeka & Santa Fé Railway 2-10-2 (Santa Fé Type). (25) May.

*Illustrated.

Railroad—(Continued).

Eight-Coupled Switching Locomotive: Chesapeake & Ohio Railroad.* (25) May.
Modern Methods of Handling Ore from Minnesota Mines to Pittsburg Furnaces.* Charles H. Wright, M. Am. Soc. C. E. (13) May 5.
Track Elevation of the Pennsylvania in Newark, N. J.* (15) May 6.
Four-Cylinder Balanced Compound Locomotive for the New York Central.* (18) May 7.
A New Electric Railway in Alexandria, Egypt.* (17) May 7.
The New Mount Vesuvius Electric Railway.* (17) May 7.
Extension of the Schenectady Railway System.* Alton D. Adams. (17) May 7.
The Key Route Electric Railway Power Plant Oakland, Cal. (14) May 7.
A Trolley Line up Mount Vesuvius.* (27) May 7.
Block Signal System. (17) May 7.
La Nouvelle Locomotive à Grande Vitesse du North Eastern Railway.* R. Bonnin. (36) May 25.
Note sur les Wagons-Tombereaux de 50 Tonnes de la Compagnie du Midi Construits en Emboutis d'Acier par les Forges de Douai.* M. Moffre. (38) Apr.
Note sur les Nouveaux Ateliers de la Société Française de Constructions Mécaniques à Denain.* (38) Apr.
Nouvelles Voitures Automobiles à Vapeur pour Voies Ferrées.* F. Barbier. (33) Apr. 9.
Les Chemins de Fer à Traction Électrique dans la Haute-Italie.* (33) Apr. 16.
Les Récents Wagons de 50 Tonnes Construits par les Forges de Douai.* (36) Apr. 25.

Railroad, Street.

The New Electricity Works and Tramways of West Ham.* (26) Apr. 8.
Rebuilding G. E.-57 Field Coils at St. Louis.* (17) Apr. 16.
A Conduit Electric Railway in London, England.* (13) Apr. 21.
Disposal of City Ashes as an Adjunct of Street Railway Business in Brooklyn.* (17) Apr. 23.
New Westinghouse Railway Motor.* (27) Apr. 23.
Compressing Stations for Storage Air Brakes at St. Louis.* (17) Apr. 23.
The Continuous-Current System and the Single-Phase System for Traction. H. M. Hobart. (26) Serial beginning Apr. 29.
Manchester Corporation Tramways. J. M. McElroy. (Abstract of Paper read before the Inst. E. E.) (73) Apr. 29.
A Regenerative System of Tramcar Control.* (73) Apr. 29.
The New Parkville Concrete Sub-Station of the Brooklyn Rapid Transit Company.* (17) May 7.
Construction Details of Toronto Convertible Car.* (17) May 7.
Some of the Electric Railway Features at the World's Fair, St. Louis.* Winder Elwell Goldsborough. (17) May 7.

Sanitary.

Plumbing in the W. T. Smith Manual Training School, Scranton, Pa.* (70) Serial beginning Apr.
Radiation or Pipe Surface. Walter Jones. (Paper read before the Inst. of Heat. and Vent. Engrs.) (70) Apr.
Heating Paper Mills. (70) Apr.
Extensions of Brooklyn Sewerage System: Avenue G. Trunk Sewer.* (14) Serial beginning Apr. 16.
The Control of Humidity by Means of the Humidostat.* W. S. Johnson, M. Am. Soc. M. E. (13) Apr. 21.
Disposal of City Ashes as an Adjunct of Street Railway Business in Brooklyn.* (17) Apr. 23.
Sewage Disposal Works and Experiments at Andover, Mass.* (14) Apr. 23.
Notes on the Sewerage System of Worcester, Massachusetts.* (14) Apr. 23.
Extensions of Brooklyn Sewerage System; Ninety-second Street Trunk Sewer.* (14) Serial beginning Apr. 30.
Progress of Construction of the New Orleans Drainage System. (14) Apr. 30.
The Cleaning and Flushing of Sewers. (14) Apr. 30.
Farington, Eng., Sewage Disposal Works. William Naylor. (60) May.
L'Humidification et la Ventilation des Ateliers dans l'Industrie Textile.* Paul Razous. (33) Serial beginning Apr. 16.

Structural.

Tensile Tests of Mild Steel; and the Relation of Elongation to the Size of the Test-Bar. William Cawthorne Unwin, M. Inst. C. E. (63) Vol. 155.
Analysis of Red and Black Paints. Chas. G. Snyder. (58) Jan.
The Reconstruction of Foundations for the Hotel Wollaton, Brookline, Mass.* Dana M. Pratt. (Paper read before the Boston Soc. of Civ. Engrs.) (1) Mar.
Conflagrations in Cities: A Topical Discussion. (2) Apr.
The Cement Age: The Many New Uses and Increasing Demand for Plastic Materials. R. W. Leslie. (2) Apr.
Concrete: Its Properties and Applications: A Topical Discussion. (2) Apr.
Reinforced Concrete in Building Construction.* Emile G. Perrot. (2) Apr.

*Illustrated.

Structural—(Continued).

Reinforced Concrete Roof for a Locomotive Roundhouse, Long Island R. R.* (13) Apr. 14.
Some Recent Tests of the Weight of Crowds. L. J. Johnson, Assoc. M. Am. Soc. C. E. (13) Apr. 14.
Some Comments on Building Laws. Gunvald Aus, M. Am. Soc. C. E. (13) Apr. 14.
The Extension of the Imperial Hotel, New York.* (14) Serial beginning Apr. 16.
Tests of Sand-Lime and Sand-Cement Brick and Concrete Building Blocks. A. Marston. (Abstract of Paper read before the Iowa Brick and Tile Manufacturers' Assoc.) (13) Apr. 21.
The Fallacy of the Tests Ordinarily Applied to Portland Cement. Richard K. Meade. (Paper read before the Amer. Chem. Soc.) (13) Apr. 21.
Loam and Clay in Sand for Concrete. G. J. Griesenauer. (13) Apr. 28.
The Construction of the Times Building, New York City.* (14) Serial beginning Apr. 30.
Specifications for Cement. (60) May.
The Building of a World's Fair.* (14) May 7.
Concrete Piles for Building Foundations.* (14) May 7.
Un Tracé Géométrique des Paraboles Cubiques et Ses Applications aux Lignes d'Influence dans les Poutres Continues.* Farid Boulad. (43) 4e Trimestre, 1903.
Sur la Flexion des Poutres Rectangulaires. M. Flamant. (43) 4e Trimestre, 1903.
Étude Physique des Materiaux de Construction. P. Malette. (36) Serial beginning Apr. 25.

Water Supply.

Pumps and Pumping Machinery.* G. A. F. Ahlberg. (58) Jan.
Water Main Tapping Machine.* (12) Apr. 8.
The Cylindrical Movable Dams at Schweinfurt, Germany.* A. Steens. (46) Apr. 16.
The Weston Aqueduct Pipe Arch over the Sudbury River, Massachusetts.* (14) Apr. 16.
Development of an Underground Water Supply for Penzance, England. (14) Apr. 16.
Earthwork at the Washington Filtration Works.* E. D. Hardy. (14) Apr. 16.
Progress in Construction of Jerome Park Reservoir, New York City.* (14) Apr. 23.
The Atlanta Water & Electric Power Company's Plant at Morgan Falls.* (14) Apr. 23.
Filter Plant and Other Improvements for the Water Supply of Danville, Ill.* (13) Apr. 28.
Studies of Color in Water; Metropolitan Water Supply, Massachusetts.* Ernest G. Hopson. (13) Apr. 28.
Underground Waters Adjacent to Surface Streams.* C. G. Hubbel. (13) Apr. 28.
Purification of Potable Water by Means of Ozone.* Gg. Erlwein. (Paper read before the Deutscher Verein von Gas-und Wasserfachmaennern.) (19) Serial beginning Apr. 30
Purification of Boiler Water.* (45) May.
The Raising of Water by Compressed Air. (60) May.
Some Examples of Electrolysis of Pipes.* (60) May.
The Use and Abuse of Direct Acting Steam Pumps.* W. H. Wakeman. (64) May.
Progress Report on the Croton River Works for New York City's Water Supply.* (14) May 7.
Appareil pour le Jaugeage des Conduites d'Eau en Service.* J. Feugères. (34) Apr.

Waterways.

Electric Canal Haulage Devices.* (18) Apr. 16.
Combination Hydraulic and Dipper Dredge for the Mexican Government.* (13) Apr. 21.
Method of Computing Daily and Monthly Discharge of Streams with Sandy, Changeable Bed.* E. C. Murphy, M. Am. Soc. C. E. (13) Apr. 21.
Notes on the Flood of March, 1904, in the Lower Susquehanna River.* John C. Hoyt and Robert H. Anderson. (13) Apr. 28.
L'Alimentation du Canal du Danube à l'Oder.* (33) Apr. 16.
Port de Marseille : Travaux de Construction du Bassin de la Pinède.* Batard-Razelière. (43) 4e Trimestre, 1903.

---

*Illustrated.

Vol. XXX. JANUARY, 1904. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS.

Vol. XXX. JANUARY, 1904. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

METHOD USED BY THE RAILROAD COMMISSION, OF TEXAS, UNDER THE STOCK AND BOND LAW, IN VALUING RAILROAD PROPERTIES.

By R. A. Thompson, Assoc. M. Am. Soc. C. E.

To be Presented February 3d, 1904.

The issuance of all kinds of railroad securities in Texas is regulated by the Railroad Stock and Bond Law, and the execution of its provisions is under the jurisdiction of the Railroad Commission. In this matter, Texas is the pioneer of the States of the Union, no other State, within the knowledge of the writer, having legislated upon the subject to the extent of having prescribed a fixed basis of value beyond which the railroads cannot increase the indebtedness to be secured by mortgage or lien upon their property. The law of Texas, in addition to controlling and regulating absolutely the issuance and execution of all stocks and bonds of railroads, defines the method which must be used by the Railroad Commission in arriving at the proper value of the properties, which shall serve as the basis for such issuance.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The Texas Railroad Stock and Bond Law was enacted in 1893, to supplement and strengthen the general Railroad Commission Act, passed by the State Legislature in 1891, which placed in the hands of a Commission, among other things, the entire control over, and regulation of, all freight rates and tariffs. The necessity for a law, limiting, on some reasonable basis, the capitalization of the railroads, and operating in connection with the control of freight charges, was obvious after some certain judgments which had been handed down shortly before by the United States Federal Courts. These decisions held, in effect, that any State tribunal affecting to control and regulate the charges on railroads for freight transported within the State, must permit the railroads to earn, in addition to the current expenses of maintenance and operation, the interest on their outstanding bonds and a fair dividend on their stock. It was considered that if the Commission elected to regulate freight charges was to be effective, it must have supervision and control over the issuance of stock and bonded securities, otherwise, by "watering" and other popular methods in vogue, the railroads could make their indebtedness as high as they chose, thereby preventing, in accordance with the decisions of the Courts, any reduction in rates that the Commission might consider reasonable.

Another reason for the enactment of the Stock and Bond Law was that the railroad securities of the State might have a real and substantial value, and that innocent purchasers might be protected. This feature of the law has been stated admirably by the Hon. John H. Reagan, ex-Chairman of the Railroad Commission of Texas, in the Second Annual Report of the Commission (1893). He says:

"This law will prevent the unlawful and fraudulent issue of stocks and bonds of railroad companies in the future in this State, and protect the people from the exactions necessary to satisfy them. It will protect the purchasers of such securities from being imposed on by them, and it will secure, to the companies who may hereafter build railroads, a real value to their property and securities, instead of a merely speculative and fluctuating value."

The Stock and Bond Law.

The Railroad Stock and Bond Law, as published under Title XCIV, Chapter 14, Revised Statutes of Texas, 1895, declares:

"Article 4584 a.—Among other things, the power and authority of issuing or executing bonds, or other evidences of debt, and all kinds of

stock and shares thereof, and the execution of all liens and mortgag by railroad corporations in this State, are special privileges a franchises, the right of supervision, regulation, restriction, and cont of which has always been, is now, and shall continue to be vested the State Government, to be exercised according to the provisions this and other laws.

"Article 4584 b.—Hereafter no bonds or other indebtedness sh be increased or issued or executed by any authority whatsoever, a secured by lien or mortgage on any railroad or part of railroad, or t franchises or property appurtenant or belonging thereto, over or ab the reasonable value of said railroad property; provided that in c of emergency, on conclusive proof shown by the company to t Railroad Commission, that public interests or the preservation of t property demand it, the said Commission may permit said bonds, gether with the stock in the aggregate, to be executed to an amou not more than fifty per cent. over the value of the said property."

It further provides, with regard to the railroads constructed a in operation at the time of the passage of the law:

"Article 4584 c.—It shall be the duty of the Railroad Commiss to ascertain and in writing report to the Secretary of State, the va of each railroad in this State including all its franchises, appurtenan and property. After it shall have prepared said report of value, t Commission shall give the company interested ten days' notice in wr ing, by registered letter to the president, treasurer or receiver of s railroad, to the effect that said report is ready to be made, and tha it have any objections thereto it must file them in writing, wit forty days after said service, or the same will be so deposited with t Secretary of State as correct. Should the company or its d authorized representative file with said Commission any objections said report of value, the Commission shall duly investigate and p on the same. On investigation, if the Commission conclude that report of value is too low or too high, then it shall make the necess correction before filing it. Should no objections be filed within t time permitted, or being filed and on examination found with merit, the Commission shall forthwith file its said report in the off of the Secretary of State, where it shall remain as a public record, a limitation for the issuance of indebtedness under the limitati prescribed in Article 4584 b. To promote public interests and prot private rights, the Commission, after due notice under the rule her prescribed, may correct its report of value of any railroad at any ti it may deem proper."

With respect to railroads constructed after the passage of t law, or existing at that time, but against which stocks and bonds w not outstanding in excess of their value, the following section defi the method of procedure to be had in making the application

tocks and bonds, and defines the basis on which the Rail-
ssion must make its valuations:

34 f.—Should any company or corporation, authorized to wn or operate a railroad in this State, desire to issue er indebtedness, to be secured by lien or other mortgage ise and property, in advance of the completion of the said hall make application to and first procure the consent of Commission thereto. In said application it shall exhibit nission its contract with the construction company, if it e profile of its completed road or part of road, the evi- right of way, depot grounds, terminal facilities; the alue of work done or in process of completion; the amount received; the amount of stock subscribed and the amount all other necessary facts showing the value of the fran- roperty proposed as security for said contemplated debts. gation, the Commission is satisfied that the company is d faith, and that its contract with the construction com- nable and fair to the public, then it shall authorize the said indebtedness and lien to the extent necessary for the he work, at no time to be more than fifty per cent. over the whole property and franchises."

nority has been obtained from the Commission to issue onds upon a railroad, and the same or any portion of it npleted, Articles 4584 h and 4584 i of the Statute, which ssary to quote here, prescribe the method of procedure tocks and bonds registered in the office of the Secretary is only after such registration that the securities become ation against the property which is mortgaged. Stocks e approved and authorized to be registered by the Com- upon and to the actual value of the completed railroad, s determined by inspection.

F RAILROADS EXISTING AT THE TIME OF THE PASSAGE OF THE LAW.

ance with the requirements of Article 4584 c, of the Stock w, it became the duty of the Railroad Commission to lroads of the State then existing, and to report their values ary of State. The basis for valuation is practically out- icle 4584 c, and was interpreted by the Commission to timated cost of duplicating or reproducing the properties of valuation, allowing current market prices for labor,

materials and equipment, and a fair value for all right of way, dep grounds and other real estate used for railroad purposes.

The engineers of the Commission employed to make these valu tions had for their guidance in making estimates of quantities grading, etc., only the profiles of the railroads, which were requir to be filed with the State under a previous statute. The railroads that time were not favorably disposed toward the Commission and t Law, and it was difficult to secure information as to their origin cost, even where the same was contained in their official records. many instances, the railroads had passed through several manag ments and receiverships, and the original construction notes and re ords had been misplaced or were entirely lost. In several cases records had been destroyed by fire.

The Railroad Commission appointed engineers to assist in makin the valuations, and they, with the profiles referred to, in hand, made detailed inspection of the railroads on the ground. The quantities excavation and embankment, where the actual quantities could not obtained, were estimated approximately from the profiles, using th center heights of the cross-sections. The classification of the m terials in excavation was determined by inspection. Where the origin plans and estimates of cost of the bridges, buildings and structur of all kinds could not be obtained from the records of the railroad their value was estimated from measurements taken on the groun The extent and acreage of the right of way, the depot and termin grounds, were determined by actual measurement, or from maj furnished by the railroads, or from the city and county tax records.

After an examination of a railroad had been made by the enginee of the Commission, its valuation was prepared on estimate sheet Upon sheets marked Estimate Sheet A, and headed "Estimate of th Value of the ——— Railroad, from Mile No. — to Mile No. —," wer recorded the values of the right of way and depot grounds, roadbed track, bridges, structures and way buildings for each mile, the valu of ten miles being recorded on each sheet. (See Items on Sheet A On these sheets space was provided for the units and prices, an columns for carrying out the values for each mile and the totals.

The value of all rolling stock and equipment, and the value of suc properties as were properly applicable and chargeable to the entir railroad, were recorded on a separate estimate sheet, only one shee being used for a railroad.

Estimate Sheet A.

Estimate of the Value of the .... Railroad, from Mile No. .... to Mile No. .....

Right of Way.

Depot Grounds. Exclusive of Round House and Machine Shop Sites and Terminal Facilities.

Graduation: Clearing and Grubbing.
Original Excavation: Earth.
Gravel.
Loose rock.
Solid rock.
Tunnels.
Original Embankment: Hauled.
Earth.
Gravel.
Loose rock.
Widening excavation.
Widening embankment.
Rip-rap.
Retaining walls.

Bridges: Foundations: Excavation, Earth.
Gravel.
Loose rock.
Solid rock.
Wet.
Coffer-dams, Pumping, Caissons, etc.
Piling.
Grillage.
Concrete.
Masonry: Abutments and Piers, First class.
Second class.
Third class.
Cylinders (length and diameter).
Culverts, First class.
Second class.
Third class.
Dry.
Trusses: Iron and Steel, Through trusses (length).
Iron and Steel, Deck trusses (length).
Combination trusses (length).
Wooden trusses (length).
Trestles: Trestle bridges (length).
Piling for Trestles (length).
Wooden box-drains (length).
Earthenware drain pipe (length and diameter).
Wooden cattle guards.
Iron cattle guards.
Fencing right of way.

Track: Ties.
Steel rails.
Iron rails.
Joints, complete.
Spikes.
Laying, including expense of two trains.
Hauling ties.
Surfacing.
Ballasting.

Telegraphs. Line complete.

Buildings: Exclusive of general offices, machine shops, round houses, etc.
Passenger depots, including platforms.
Freight depots, including platforms.
Cotton platforms.
Sundry warehouses.
Train sheds.
Section houses.
Water stations.
Stock pens.
Coal chutes.
Wharves.
Turntables.
Track scales.
Road crossings and sidewalks.
Signs, of all kinds.

On the sheet for the rolling stock, space is provided for the description, number, rate and value of all locomotives and cars.

The locomotives are classed as "Passenger," "Freight" or "Switch Locomotives," and there are columns headed as follows: Gauge, Maker, Size of Cylinders, Wheel Base, Length of Engine, Total Length of Engine and Tender, Weight on Drivers, Weight of Engine, and Total Weight of Engine and Tender.

The cars are classed as follows:

Passenger Cars.	Freight Cars.	Maintenance and Other Cars.
Passenger cars, first class.	Box cars, 34 ft. long and over.	Officers' cars.
" " second class.	" " 32 to 34 ft.	Office cars.
Sleeping cars.	" " less than 32 ft.	Pay cars.
Chair cars.	Stock cars, 34 ft. long and over.	Boarding cars.
Dining cars.	" " 32 to 34 ft.	Water cars.
Buffet cars.	" " less than 32 ft.	Wrecking cars.
Baggage cars.	Flat cars, 32 ft. and over.	Derrick cars.
Postal cars.	" " less than 32 ft.	Pile-driver cars.
Baggage and mail combined.	Gondolas.	Excavator cars.
Express cars.	Coal cars, 60 000 lbs. capacity.	Dump cars.
Combination passenger and baggage cars.	" " ordinary.	Iron cars (track laying).
Emigrant cars.	Tank cars.	Push cars.
	Refrigerator cars.	Hand cars.
	Cabooses.	Velocipedes.

Other items are included in the following:

Maintenance of Way Dept.:	*Machine and Repair Shops:*	*Franchises and Real Estate:*	*Miscellaneous:*
Excavators on cars.	Stationary engines and other power in shops.	Other than right of way and depot grounds proper.	Legal expenses during construction.
Wheel scrapers.	Machine tools.	General offices.	Engineering expenses during construction.
Drag scrapers.	Other shop tools in use.	Machine and repair shops.	Superintendence during construction.
Plows.	Other shop tools in storehouse.	Round houses.	Damages contingent on accident.
Other road tools in use.	Transfer tables.	Terminal grounds.	Damages contingent on land.
Other tools in storehouse.	Travelers.	Other yard extensions.	Furniture and fixtures, general offices.
Bridges and Buildings Dept.:	Other hoisting appliances.	Hospitals.	Furniture and fixtures, elsewhere.
Pile-drivers on cars.		State charter.	Stationery.
Pile-drivers, ordinary.		County franchises.	Interest during construction.
Derricks on cars.		Municipal franchises.	*Materials and Supplies:*
Derricks, ordinary.			Roadway Dept.
Barges and scows.			Bridges and Buildings Dept.
Other bridge tools in use.			Machine and Locomotive Dept.
Other bridge tools in storehouse.			

The values applied to the several unit items of construction, materials and equipment were the current market (contract) prices for the same, a liberal allowance being made for contingencies. The values applied to the right of way and other real estate owned by the railroads, but used strictly for railroad purposes, were in accordance with the current market value of the adjoining property. No deductions were made for any property which had been donated or which had been acquired by the railroads at less than its market value, but all was valued on the basis described. The value applied to the grading quantities was the outside market (contract) price prevailing. The values applied to lumber, rails, and the other materials of construction were the market quotations, with due allowance for freight charges to the point of construction. No deduction was made for depreciation in the value of materials on account of age, wear and tear, usage, etc., it being considered that the roadbed, track and all structures must be maintained in first-class and serviceable condition, and renewed from time to time, whenever necessary. On the other hand, no additional allowance was made for the value of seasoned roadbed, etc.

In accordance with the instructions of the Commission, no allowance was made for franchises of any kind except municipal franchises, and in that case only where the streets of a city or town were occupied by the tracks of a railroad in lieu of the purchase of adjoining property. The value then applied to such a franchise was a certain percentage of the estimated market value of abutting properties on each side of the street, less the value of the improvements thereon, usually about 33⅓ per cent.

An arbitrary allowance, usually from 5 to 6% of the total estimated value of the railroad, was made to cover all the items "legal and engineering expenses and superintendence." A similar allowance was also made for the item "interest during construction."

These valuations, after being summarized, were reported to the Commission, and, upon being adopted by it, were transmitted to the office of the Secretary of State for permanent record in his office, due notice, in accordance with the statute, having been given to the railroads.

VALUATION OF THE NEW RAILROADS UPON WHICH THE ISSUANCE AN REGISTRATION OF STOCKS AND BONDS IS APPLIED FOR.

In accordance with the provisions of Article 4584 f, of the Statut heretofore quoted, whenever any new corporation desires to constru a railroad, or whenever any existing company desires to make exte sions of its system, authority can be had from the Railroad Commi sion to issue stocks and bonds in advance of the completion of t railroad, provided the rules and regulations of the Commission go erning in such matters are complied with. These require that least an actual survey of the proposed railroad shall have been mad and sufficient right of way secured, either by deed or contract, show the good faith of the company. This authority to issue bond secured from the Commission in advance of the completion of t railroad, however, is of little value to the company except as a gua anty that when a certain railroad is completed in accordance with t plans and specifications filed with the application for issuance stocks and bonds, the Commission will approve and direct the registration in the office of the Secretary of State, after which th become a valid obligation against the property. This authorit upon several occasions, has been used as the basis for constructi and equipment contracts.

From the plans, specifications, contracts and other exhibits file with an application for issuance of stocks and bonds, an estimate the ultimate physical value of the railroad, when completed, is ma by the Commission, upon the basis heretofore described, and t issuance of stocks and bonds authorized to the amount of the estima As before, due allowance is made for the value of all property whi is to be donated to the railroad, which is to be used for strictly ra road purposes, and for municipal franchises which are to be actual occupied.

The estimate upon which the issuance of stocks and bonds based is made up on Estimate Sheets A, B and C, which are prepar by the Commission. One sheet, of the form "Estimate Sheet A", used for each mile of railroad, and, in the first column, under t heading, "Estimate Upon Which Authority to Issue Stock and Bon Is Based," is placed the rate per unit item allowed, and the amou and value of each item of property and construction which is to ent

into the ultimate valuation of the railroad, except rolling stock and equipment, and such general items as are more properly chargeable to the entire line. These latter items are considered and the values applied are recorded on the form, "Estimate Sheet B and C," under the same heading as before, one sheet being used for the entire railroad. The total of these estimate sheets determines the amount of stocks and bonds that the Commission will authorize to be issued.

After the railroad, or any section of it, has been completed, *viz.*, the track laid and surfaced, application can then be made to the Railroad Commission for its approval and authority to register, of the stocks and bonds already authorized to be issued, an amount equivalent to the value of the completed railroad or section thereof. The Commission has its engineer make an inspection of the railroad reported to be completed, and, upon Estimate Sheets A, B and C, above mentioned, in the next column, under the heading, "Estimate for Registration of Stock and Bonds," is recorded the value, of the property acquired and construction completed, applicable. Upon approval of the engineer's report of value, the Commission orders the registration of the stocks and bonds.

As subsequent sections are completed, the Commission will authorize additional stocks and bonds to their value. Also, upon the completion at any time thereafter of any construction, or the acquirement of any property, contemplated in the original application upon which the issuance of the stocks and bonds was based, such as permanent bridges, ballasting, fencing, buildings, terminal grounds, etc., additional bonds will be authorized registered to their value as the same appears on the first estimate made by the Commission. The value of these latter items are entered in the last column of Estimate Sheets A, B and C.

In any case, however, whether or not the same was contemplated or was specified in the original application for issuance of stocks and bonds, since it is provided in Article 4584 b that the aggregate amount of stocks and bonds must not exceed the reasonable value of the property, any railroad can at any time apply to the Commission for authority to issue and register additional stocks and bonds to the amount of the value of any permanent improvements, betterments and equipments which have been added to the property or acquired by the company.

ESTIMATE SHEET; "A," ROADBED, STRUCTURES, ETC.

RAILROAD COMMISSION OF TEXAS.

____________ *Rail* ______, *Mile No.* ______ *From* ____________

Item.	Estimate Upon Which Authority to Issue Stock and Bonds is Based. Made..............190..				Estimate for Registration of Stock and Bonds. Made......190..			Estimate for Registration of Stock and Bonds. Made......190..		
	Rate.	Unit.	Amount.	Value.	Rate.	Amount.	Value.	Rate.	Amount.	Value.
Right of Way............		Acre.								
Depot Grounds...........		"								
Clearing and Grubbing..		"								
Earth Excavation........		"								
Gravel Excavation.......		"								
Loose Rock Excavation.		"								
Solid Rock Excavation..		"								
Earth Embankment......		"								
Hauled Embankment....		"								
Rip-Rap..................		"								
Foundation Excavation..		"								
Foundation Piling........		lin. ft.								
Grillage..................		B. M.								
Masonry Piers...........		cu. yd.								
Cylinder Piers...........		lin. ft.								
Masonry Culverts........		cu. yd.								
Steel Trusses............		lb.								
Plate Girders............		"								
Trestle Timber...........		B. M.								
Trestle Piling............		lin. ft.								
Drains, Box.............										
Drains, Pipe.............		lin. ft.								
Cattle Guards............		Each.								
Fencing.................		Mile.								
Road Crossings..........										
Signs.....................										
Ties......................		Each.								
Tie-Plates................		"								
Steel Rails...............		Ton.								
Joints Complete..........		Each.								
Spikes...................		Keg.								
Laying and Surfacing...		Mile.								
Sidings..................		lin. ft.								
Switch Furniture........		Set.								
Railroad Crossings......										
Ballast..................										
Telegraph...............		Mile.								
Passenger Depot.........		Each.								
Freight Depot...........		"								
Cotton Platform.........		sq. ft.								
Section House...........		Each.								
Water Station...........		"								
Stock Pen...............		"								
Coal Chute..............		"								
Track Scales............		"								
Total...............										

Mile No. ______ *From* ____________ *Rail* ____________

ESTIMATE SHEET; "B," ROLLING STOCK.
ESTIMATE SHEET; "C," MISCELLANEOUS ITEMS.

RAILROAD COMMISSION OF TEXAS.

_____________ *Rail* _____

ITEM.	Estimate Upon Which Authority to Issue Stock and Bonds is Based. Made........190..			Estimate for Registration of Stock and Bonds. Made........190..			Estimate for Registration of Stock and Bonds. Made........190..		
	No.	Rate.	Value.	No.	Rate.	Value.	No.	Rate.	Value.
Passenger Locomotives									
Freight Locomotives									
Switch Locomotives........									
Passenger Cars............									
Chair Cars.......									
Baggage Cars..............									
Express Cars..............									
Postal Cars...............									
Combination Cars..........									
Officers' Cars............									
Box Cars.............									
Flat Cars.................									
Stock Cars................									
Coal Cars.................									
Tank Cars.................									
Refrigerator Cars									
Water Cars................									
Hand Cars....									
Push Cars.................									
Total "B"...........									
"C" MISCELLANEOUS:									
Road Tools................									
B. & B. Tools.............									
Machine Tools									
Machine Shops.............									
Machinery									
Round Houses..............									
Turntables..........									
Furniture, Etc............									
Stationery................									
Materials and Supplies									
Terminal Grounds..........									
Franchises									
Charter Fees, Etc.........									
Legal and Engr. Expenses .									
Interest during Constr									
Total "C"...........									
Totals "B" and "C."									

_____________ *Rail* _____

No allowance is made, in the estimates of the Commission, for d count on bonds, brokerage, etc., it being considered, theoretical speaking, that the stocks and bonds represent, dollar for dollar, actu physical values. The margin for any discount on bonds or profits construction, which the promoters and builders of railroads in Te have, is therefore confined to the value allowed for the donations ma to the railroad by outside interests, and the difference, if there be a on the positive side, between the actual cost of the railroad and value as the same may be estimated by the Commission.

The emergency clause of the law, given in Articles 4584 b a 4584 f, which permits the Commission to authorize the execution indebtedness 50% in excess of the actual value of the property, as may determine the same to be, has been invoked a number of times the railroads to cover such items as discount of bonds, brokerage, et but the Commission has in all cases refused to exercise its prerogat in the matter, holding uniformly that it is the intention of the l that the said emergency provision should be invoked only in cases cover losses by railroads from extraordinary causes, such as fi floods, etc.

Rules and Regulations Controlling the Railroad Commission Texas in Issuance of Railroad Stocks and Bonds.

"For the information of the public and to secure the protection investors contemplated by the law governing the issuance and reg tration of railroad stocks and bonds, the Commission has prescrib the following as the method of procedure under the law necessary secure its authority to issue and have registered railroad stocks a bonds:

"APPLICATION FOR AUTHORITY TO ISSUE BONDS.

"An application to the Commission for authority to issue bon must set forth in the body of the application, or as an exhibit theret the following facts which must be signed by the president a attested by the secretary of the company making the application:

"1st. Copy of the company's charter.

"2nd. Copy of the published notice to stockholders calling meeting thereof for the purpose of authorizing the directors of th company to apply to the Commission for authority to issue bonds, an a copy of the resolutions adopted at such meeting of the stockholde authorizing the directors to apply to the Commission for authority issue bonds.

"3rd. The contract with the construction company proposing construct the road, if any.

"4th. Alignment map of located road, on a scale of not less than 000 feet to the inch, showing property, city and county lines.

"Deeds to right of way and other real estate acquired by the cor-ration for railroad purposes, duly attested. These must have ference to the maps, and property; city and county lines should be operly tied to the located line of the railroad in the customary anner.

"If there be lands traversed by the located line to which title has t been acquired by the corporation at the time of application, hether by reason of delay consequent upon the necessity of con-mnation proceedings, or from other causes satisfactory to the Com-ssion, the deeds thereto shall be filed with the Commission as they ay be obtained, and their description noted in place upon the maps.

"Any change that may be made in the located line of the railroad her before or during construction must be reported to the Commis-n in order that the same be duly recorded, awaiting the final action the Commission.

"Maps of station grounds, yards and terminals, on a scale of not s than 200 feet to the inch, showing locations of tracks, buildings d other structures, and their relation to the streets, blocks and lots the town or city in which they are situated, if any.

"Profile of located or completed road or part of road on a scale of t less than 400 feet to the inch horizontal, and 30 feet to the inch rtical, showing the following: Nature of timber on right of way iginally, if any; quantities of excavation and embankment and their ssification; location and length of sidings and spurs; location of ter stations and nature of supply; location and character of bridges, ildings, and all other way structures.

"Plans and specifications for the following: Graduation; ballast d track; bridges, buildings and other standard structures.

"Rolling stock: Number and class of locomotives; number and ss of cars of all kinds; miscellaneous equipment.

"Detailed estimate of the cost of the proposed or completed road.

"5th. The extent and value of work already done or in process of mpletion.

"6th. Amount of money and amount and value of property re-ived as donations to the company.

"7th. Aggregate amount of stock subscribed to the capital of the mpany and amount paid thereon.

"8th. Any and all other facts showing the value of the franchises d property offered as security for the contemplated issue of bonds.

"The following statement must accompany the application as an hibit:

"List of subscribers to capital stock, number of shares subscribed each, amount of stock represented by each share, and amount of

cash, labor or property paid thereon. Opposite each name on list must be affixed a number beginning with one, or the next hig number of any certificate of stock previously issued. Said state must be certified to by the president of the board or presiding o of the meeting at which such stock was authorized, as correct and the same in person. Said statement or certificate must be entered the minutes of the board, attested by the secretary thereof, with company seal affixed thereto and deposited with the Railroad mission. (See Sec. 7 of An act to regulate issuance of railroad st and bonds.)

"Upon the filing of such application, and a full compliance the law, the Commission will issue an order granting the corpora applying therefor authority to issue its bonds to become a first lie its franchises, property and completed road or part of road, bonds to be approved and directed to be registered only on compl road, or part of road, to the extent of the value thereof as ascerta by the Commission.

"APPLICATION FOR APPROVAL AND REGISTRATION OF BONDS BY T COMMISSION.

"Application to the Commission to approve bonds and have t registered in the Secretary of State's office must set forth under of the president of the company making the application:

"1st. The amount of stock of said company.

"2nd. The amount of outstanding bonds, if any.

"3rd. The number of miles of completed road or part of upon which the bonds are to become a first mortgage.

"The bonds presented for approval and registration must be cuted in accordance with Section 8 of the act regulating the issu of the same.

"Upon filing of each application and the presentation of the b desired to be approved and registered thereunder the Commission direct its engineer to inspect the road or part of road completed, ascertain if it has been constructed and equipped in accordance the specifications and the profile set out in its application to the C mission for authority to issue bonds. If it finds that said compl road or part of road proposed as security for the bonds presented approval and registration has been built in good faith and that worth the amount for which it is proposed as security, an order be issued to the Secretary of State directing him to register bond the extent of the value of said completed road or part of road.

"No bonds will hereafter be approved and directed to be regist by the Secretary of State except upon roads or parts of roads c pleted and equipped, and then only to the amount of the value the as determined after investigation by the Commission.

"REGISTRATION OF STOCKS.

"The issuance of certificates of railroad stock to subscribers to he capital stock must be in accordance with Section 7 of the act reguting the issuance of railroad stocks and bonds and must be only on ompleted road or part of road. When so issued the Commission will irect their registration in the office of the Secretary of State.

"The amount of the stocks and bonds together in the aggregate ust not exceed the reasonable value of the property of the company suing them."

Railroads Which Have Been Valued by the Commission.

Since the passage of the Stock and Bond Law, the Railroad Comission has, from time to time, valued the railroads of Texas, and led its valuations with the Secretary of State. Table No. 1 is a list f the railroads which have been valued, up to October 20th, 1903, gether with their valuations, as the same will appear in the Twelfth nnual Report of the Railroad Commission, 1903.

Effect of the Stock and Bond Law.

In connection with the foregoing statement of the Railroad Stock d Bond Law of Texas and the description of the methods used by the ailroad Commission when valuing railroads, under its provisions, it ill no doubt be of interest to mention what the general effect of the w has been on the railroad securities of the State. Table No. 2, hich will appear in the Twelfth Annual Report of the Railroad ommission of Texas, 1903, very briefly, but effectually, shows the rincipal effect of the Stock and Bond Law, which has been to reuce steadily the average outstanding indebtedness of the railroads f Texas, per mile, and this has been done in the face of an actual ncrease in physical values and an increase in net earnings of the roperties.

When it is considered that all indebtedness of the railroads outtanding at the time of the passage of the Stock and Bond Law emained in effect, and is still in effect, it will be seen that the reducion in the average indebtedness per mile of the railroads of Texas as been due largely to the restriction which the law placed on the ssuance of securities for the 1 875 miles of new railroad which

have been constructed since the passage of the law, and such old railroad as was sold out, at receiver's, or other sale, and reorganized.

TABLE No. 1.

Name of railroad.	Mileage.	Valuation.	Value per mile.
Beaumont Wharf and Terminal	3.06	$179 481	$58 273
Cane Belt	68.69	830 968	12 097
Chicago, Rock Island and Mexico	91.75	1 475 361	16 080
Chicago, Rock Island and Texas	147.29	2 760 423	18 741
Dallas, Cleburne and Southwestern	9.77	155 917	15 959
Denison, Bonham and New Orleans	24.11	375 266	15 565
Eastern Texas	30.41	454 528	14 947
Fort Worth and Denver City	454.18	5 771 582	12 709
Fort Worth and Rio Grande	143.10	2 003 839	14 003
Galveston, Harrisburg and San Antonio	919.06	16 142 298	17 564
Galveston, Houston and Henderson	48.85	1 527 023	31 259
Galveston, Houston and Northern	56.36	1 000 000	17 743
Gulf, Beaumont and Kansas City	67.55	676 485	10 015
Gulf, Beaumont and Great Northern	58.22	853 123	14 653
Gulf, Colorado and Santa Fé	987.84	16 649 746	16 863
Gulf, Western Texas and Pacific	109.67	1 318 082	12 019
Hearne and Brazos Valley	16.42	106 624	6 493
Houston and Texas Central	690.42	13 683 834	19 820
Houston, East and West Texas	190.69	2 042 698	10 712
International and Great Northern	1 049.93	19 928 547	18 981
Missouri, Kansas and Texas of Texas	1 069.83	16 688 500	15 599
New York, Texas and Mexican	122.93	1 464 206	11 911
Orange and Northwestern	32.80	458 793	13 987
Paris and Great Northern	16.18	288 718	17 844
Pecos River	54.13	392 405	7 249
Red River, Texas and Southern	57.49	1 215 352	21 140
Rio Grande	22.17	310 551	14 008
Rio Grande and Eagle Pass	26.89	234 695	8 729
Rio Grande and El Paso	20.15	481 824	23 912
St. Louis, San Francisco and Texas	6.74	407 454	60 453
St. Louis Southwestern of Texas	652.51	10 057 889	15 706
San Antonio and Aransas Pass	687.67	8 677 698	12 619
Southern Kansas of Texas	114.95	1 190 672	10 358
Sugarland	14.12	109 415	7 749
Texarkana and Fort Smith	79.24	1 603 789	20 240
Texas and Louisiana	21.91	203 688	9 297
Texas and New Orleans	433.14	8 667 796	18 896
Texas and Pacific	1 039.33	17 730 689	17 060
Texas Central	215.36	2 885 256	13 397
Texas Mexican	162.40	1 457 638	8 976
Texas Midland	112.49	1 914 578	17 020
Texas, Sabine Valley and Northwestern	38.41	398 848	10 384
Texas Southern	68.69	743 980	10 831
Velasco, Brazos and Northern	20.06	240 656	11 997
Weatherford, Mineral Wells and Northwestern	23.00	327 496	14 239
Wichita Falls	17.96	242 888	13 521
Wichita Valley	51.36	486 768	9 478
Total	10 348.75	$166 817 992	$16 120

This reduction in the average indebtedness per mile of the railroads of Texas will continue as long as the Stock and Bond Law remains in effect, and until their capitalization approaches the physical value of the properties, as it may be determined by the Railroad Commission.

TABLE No. 2.

n June 30th.	Miles of railway in operation.	Stocks outstanding, per mile.	Bonds outstanding, per mile.	Total stocks and bonds outstanding, per mile.
4.............	9 154	$15 076	$25 726	$40 802
5.............	9 291	14 874	25 420	40 294
6.............	9 437	14 647	25 302	39 949
7.............	9 484	14 320	24 798	39 118
8.............	9 540	14 205	24 036	38 241
9.............	9 702	13 997	23 562	37 559
0.............	9 867	13 724	23 202	36 926
1.............	10 154	12 922	22 649	35 571
2.............	10 617	12 388	21 779	34 167
3.............	11 029	11 971	21 464	33 435
Total reduction for 9 years...		$3 105	$4 262	$7 367
erage reduction per year for) years.........................		$345.00	$473.55	$818.55

Vol. XXX. JANUARY, 1904. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

FREEZING AS AN AID TO EXCAVATION IN UNSTABLE MATERIAL.

By James H. Brace, Assoc. M. Am. Soc. C. E.

To be Presented February 17th, 1904.

Introduction.

This paper contains a synopsis of the result of a research of the literature on the above subject. The research was the joint work of H. F. Dose, M. Am. Soc. C. E.; Paul A. Seurot, Assoc. M. Am. Soc. C. E., and the writer.

All articles which could be found in the various libraries of New York City were examined and abstracted, and then combined in the following synopsis. The French and German periodicals were read and translated by Messrs. Dose and Seurot, and those in English were abstracted by the writer. Lists giving the names of the various publications from which information has been obtained have been filed in the Library of the Society, where they may be referred to by those who are interested. Acknowledgments cannot be made in each case, but are due to all the sources thus listed.

History.

For many years the miners of Siberia have taken advantage of the extreme low temperature in winter to penetrate beds of quicksand

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

verlying mineral deposits. Natural refrigeration, however, can have nly a limited application in regions of severe winters.

As far as the writer has been able to ascertain, the first use of conelation produced by artificial means, as an aid to excavation, was in ngland, in 1862. In order to sink a well through a bed of quicknd, a coil of pipes, of a diameter larger than that of the lining, was ink into the quicksand. Brine, cooled by an ether machine, was cirilated through the coil until the material was frozen. The well was hen excavated without difficulty.

In 1883, F. H. Poetsch made the first application of his process, the Archibald Mine, in Saxony. Since that time, progress has een mainly along the line of improvements in his original process.

At least two other processes, the Gobert and the Koch, have been rought forward, but the only essential difference, between these sysms and that of Poetsch, is in the medium used for transferring the w temperatures from the machine to the freezing pipes.

The Poetsch Process.

Water-tight tubes, usually parallel to each other, are distributed roughout the mass to be frozen, and are known as the freezing ibes. In practice, they have usually varied from about 4 to 10 ins. diameter. Inside each freezing tube, smaller pipes, known as the rculating tubes, are placed. Each of the latter has an opening near e bottom into the outer pipe. The circulating tubes are all joined gether, usually, by a large circular or rectangular pipe, known as e circulating ring. The freezing pipes are capped at the top and ined to a similar ring, called the collector ring. A circuit is formed y connecting the circulating and collector rings to the cold-brine nk of some form of freezing machine. A pump is placed between e refrigerator and the circulating ring. Cold brine is drawn from the ottom of the tank, forced by the pump through the circulating rings, own the circulating pipes, thence up the freezing tubes, where it abrbs a certain amount of heat, and back through the collector ring to e top of the refrigerator. The circulation is maintained in this anner until an ice wall is formed completely surrounding the area be excavated.

Freezing Tubes.—The first operation, usually, is boring for the reezing tubes. The holes are put down by one of the well-known

methods. The one chosen depends largely on the nature of the material. In the earlier applications of the Poetsch process, the casings of the bore-holes were used for the outer or freezing tubes.

Considerable difficulty was found in closing the lower ends of the casings so that the brine could not escape. Also, the joints in the casings were often defective, and leaked, after the severe strains to which they were subjected in being forced down. The escape of the freezing medium, even in small quantities, prevents congelation of the impregnated strata, and thus causes a weak place, if not a leak, in the ice wall. In nearly all the work, of late years, a pipe somewhat smaller than the casing is lowered inside and the casing withdrawn. This pipe is sealed at the lower end, and each joint in turn is tested under heavy water pressure. Another cause of leaks is the contraction of the pipes under the low temperatures.

The partially frozen earth, especially where the shaft is deep, often obtains such a hold on the tube as to render movement impossible. If any further contraction takes place the pipe is ruptured and a leak produced. As a remedy for this, in at least two shafts sunk recently, slip joints have been placed at about mid-depth on the pipes.

In the first sinkings, 8 or 10-in. pipes were used, but, in late years, the diameter has usually been from 4 to 6 ins.

Circulating Pipes.—The circulating pipes have commonly been from 1 to 1½ ins. in diameter. They are either supported by the fittings at the top, or bear on the bottom of the freezing tubes. In the first case, their lower ends are left open for the passage of the descending freezing liquid. In the latter case, slots are provided in the sides near the bottom for the same purpose. The fittings at the top of both the circulating and freezing pipes are well shown in Fig. 1.

Arrangement of the Freezing Tubes.—In the first shafts built by this process, tubes were distributed throughout the area to be excavated, as well as on a ring outside. Later, only one tube was put down inside the limits of the sinking, and that usually in the center. In some cases this tube was insulated so as to freeze only the bottom of the shaft. In the latest cases, the central tube has been omitted altogether, at least for freezing purposes. It is a common practice to sink a well, of a greater diameter than that of the ring of pipes, down to the ground-water level, and then start the borings from the bottom of the well. In many cases, particularly where the shafts had been

PIPE CONNECTIONS.
CHAPIN MINE.

From the *School of Mines Quarterly*,
Vol. XI.

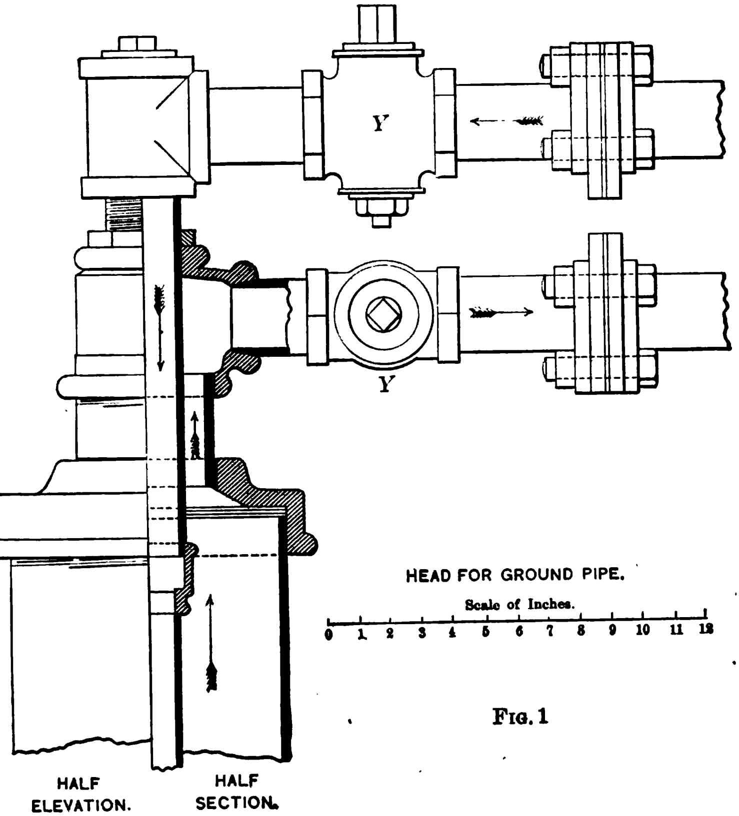


Fig. 1

started by other methods, regular arrangements of the tubes were not practicable.

In the case of the Archibald shaft, and in the second attempt at the Jessenitz shaft, all the pipes were placed inside the area to be excavated. It was found that when the pipes were uncovered they would not long maintain the ice wall. This was especially true at the Jessenitz shaft.

Circulating and Collector Rings.—The circulating and collector rings, usually, are made circular or rectangular, according to the arrangement of the outside ring of pipes. The rings are generally placed near the top of the freezing tubes, but experience has shown that the tubes should be extended above the ground-water level, so that all flow into the shaft can be stopped. Valves are provided, on the connection between the rings and tubes, in order that any tube may be cut out in case of leakage. These valves also afford a means of regulation if the freezing action in one tube takes place more rapidly than in its neighbors. It does not appear that they have been used much for this purpose.

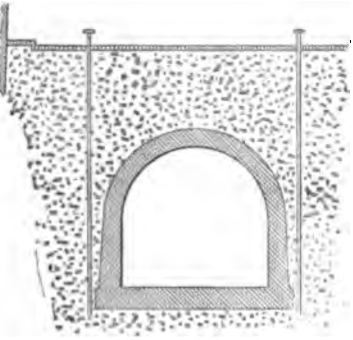
In some cases, as at the Auboué shaft, trouble has been caused by individual tubes becoming choked and stopping the circulation. The stoppage may be caused by scales of rust falling to the bottom of the larger tube and closing the end of the inner tube, or by some foreign substance which gets into the tube through the brine. When the temperature of the air around the tops of the pipes is high, a stoppage of the flow soon becomes apparent by the melting of the frost on the pipes and connections. When the temperature is low, however, as in winter, there is no means of knowing when a stoppage occurs. To remedy this state of affairs, M. Gobert has suggested the arrangement shown in Figs. 4 and 5. By this plan the tubes which receive the cold solution first would have more effect, and the refrigeration would be irregular. To obviate this difficulty, the inventor suggests reversing the current at frequent intervals.

Mr. Cavallier, with the same object in view, proposes to retain the circulating rings, but use separate return pipes from each freezing tube.

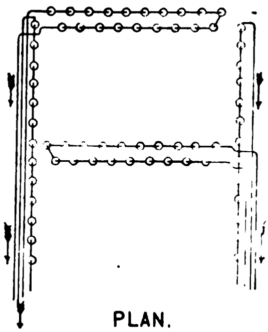
Refrigerating Machinery.—Many different types of refrigerating machinery have been used, and any device that will cool the freezing solution down to about —20° or —25° Cent. will answer the purpose.

GOBERT PROCESS.

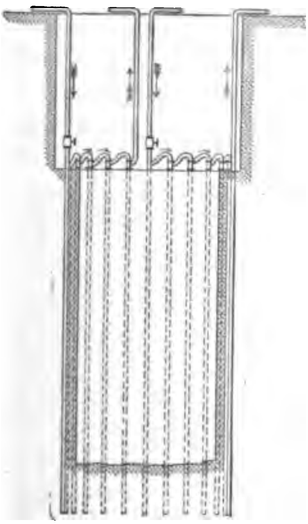
From *Transactions* of the Institution of Mining Engineers, 1902.



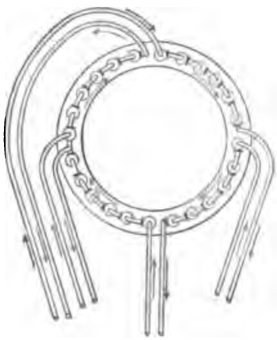
SECTION.
FIG. 2



PLAN.
FIG. 3



SECTION.
FIG. 4



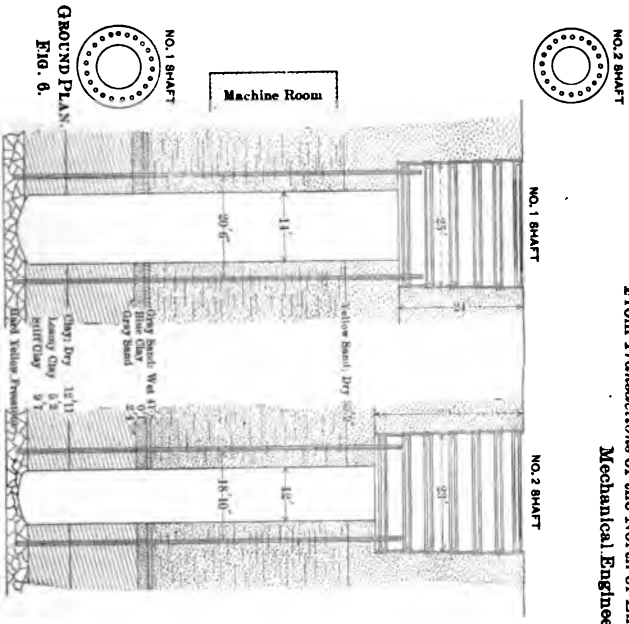
PLAN.
FIG. 5

It may be interesting to describe briefly the plant which was used at Washington Colliery, in County Durham, England, shown in plan Fig. 9. The plant consisted of the driving engine, *A*, the compress *H* and *I*, the condensers, *J* and *K*, the refrigerator, *L* and *M*, and circulating pump. The latter, of course, was a part of the circulat system, rather than of the refrigerating plant. Anhydrous ammo NH_3, was compressed to a pressure of 150 lbs. per square inch in cylinders, *H* and *I*. From the compressors it passed to the condens *J* and *K*. These consisted of tanks containing coils of 1-in. pi about 1 600 ft. long. Cold water was circulated through the tan and was kept in constant motion by the paddles, *p* and *d*. The from the compressors, in passing through the coils, gave up a c siderable portion of its heat to the cooling water, and in doing changed from a gas to a liquid. About 4 000 galls. of water per h were required for this purpose, and its temperature was raised ab 10° Centigrade.

The refrigerators were similar to the condensers, except that liquid outside the coils was the freezing solution, and the coils w 2 000 ft. long. The liquid ammonia from the condensers was admit to the coils of the refrigerators by a valve, which reduced its press to 15 lbs. per square inch. By this change of pressure the ammo again assumed its gaseous form, but in doing so it had to absorb fr the surrounding freezing solution an amount of heat corresponding its latent heat of vaporization. From the refrigerator the gas returned to the compressor, where it was again compressed and star on a second circuit.

The cold brine was drawn from the bottom of the refrigerator b pump and forced through the freezing system back to the top of refrigerator. The brine was circulated at the rate of 144 galls. minute. The temperatures of the brine, on leaving and returning the cooling tank during the different stages of the process, are sho in Fig. 10.

The freezing plant is usually located as near the top of the sh as practicable, in order to avoid loss of efficiency in transmitting freezing solution. There seems to be some difference of opinion a the amount of this loss. Mr. Moran states that the pipes ab ground at the Chapin Mine were not protected in any way, but " mediately after starting congelation, condensation of moisture coa

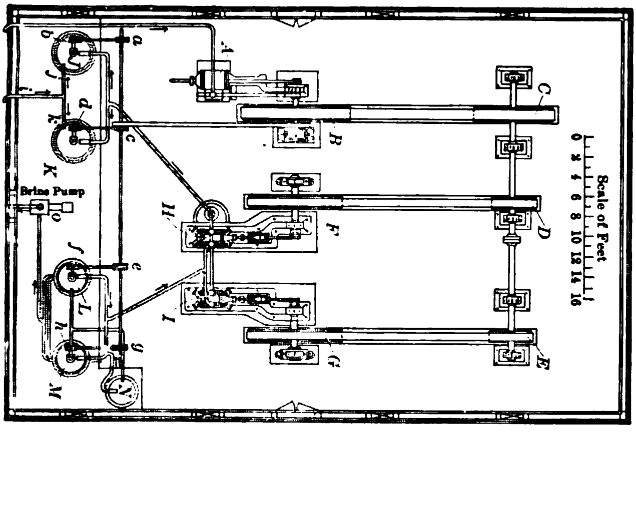


GROUND PLAN.
FIG. 6.

FIG. 7

FIG. 8

WASHINGTON SHAFT.
From *Transactions* of the North of England Institute of Mining and Mechanical Engineers, Vol. LII.



them with a snow-like ice that served as a cheap and effective laggin
On the other hand, Saclier and Waymel state that the loss at the V
Pits, where one plant was used for simultaneous work at two sha
121 ft. apart, was 20% at the surface. Arrangements must be made
supply the machine with a considerable quantity of cool water, ab
4 000 galls. per hour, and to dispose of it after it has passed throu
the condensers. If such a supply is not available, means must
provided for cooling the condensing water.

Experience has shown that the freezing plant should consist of
least two complete units, as a total stoppage of congelation may
followed by serious results.

TEMPERATURES OF BRINE AND COOLING WATER, AT WASHINGTON SHAFT.
From *Transactions* of the North of England Institute of Mining and Mechanical Engineers, Vol.

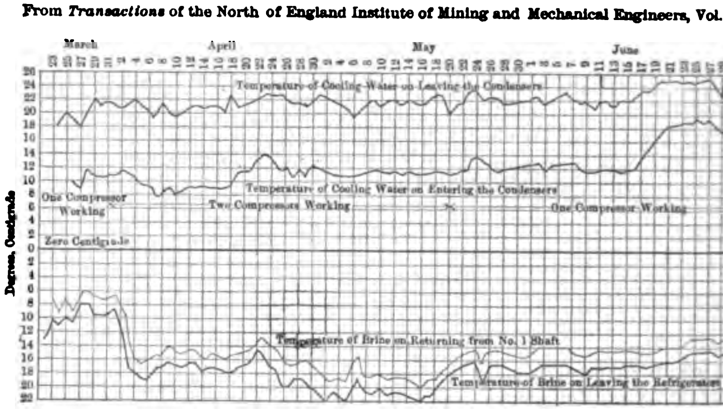


Fig. 10.

Congelation.—The progress of congelation in uniform material
well illustrated in Fig. 12. During the first stage, cylinders of
form around the individual pipes, and increase uniformly in all dir
tions until adjacent cylinders touch and form a closed wall. In
second stage, after the wall is formed, each cylinder tends to incre
in the manner shown by the dotted lines around the tube, *a*. T
cylinders, however, interfere with each other, and produce the flut
annular ring, *b*. This ring increases in thickness much more rapi
inside the ring of the pipes than on the outside. This is explained
the facts that the loss by conduction is much less toward the cent
and that the area affected by each tube is greater on the outsi
Where deep shafts penetrate impervious beds overlying heavily wat

PROGRESS OF FREEZING, STRENGTH OF FROZEN MATERIAL, ETC.
From *Colliery Guardian*, Vol. 71.
TO ACCOMPANY DESCRIPTION OF POETSCH PROCESS.

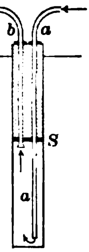


FIG. 11

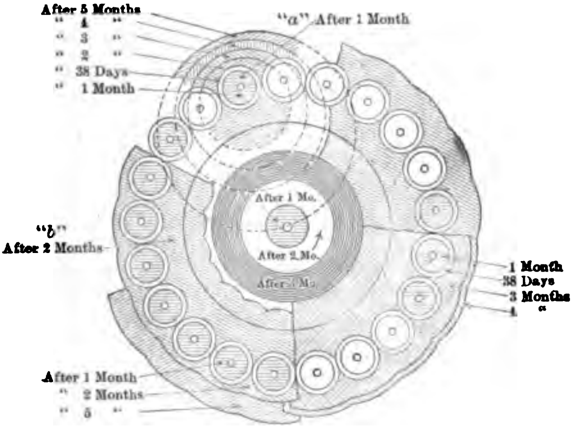


FIG. 12

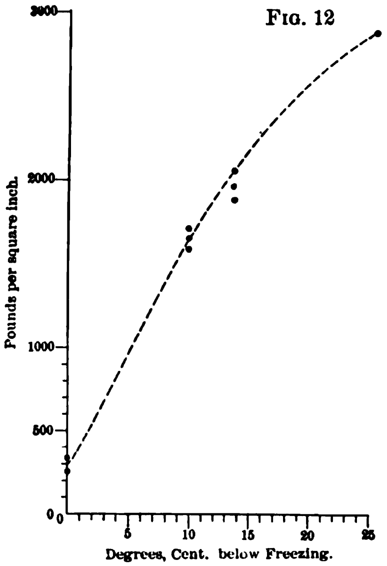


FIG. 13

bearing strata, some apprehension has been felt for the safety of the ice wall. This condition is shown in Fig. 14, illustrating the conditions at Harchies. After the impermeable clay, which congeals much more rapidly than the greensand, has completely frozen inside the circle of pipes, there will be no escape for the water confined in the space, *A*, and expanding constantly under the influence of the lowering temperature. To meet this contingency, the central pipe shown in Fig. 14 is provided. This pipe is described more fully in the account of the Harchies shaft.

The difficulties of congelation are increased by running water, or by the presence of salt water or other substances which do not freeze readily.

The strength of the frozen material varies greatly with the nature of the material itself, with the quantity of water present, and with the temperature.

HARCHIES SHAFT.

From *Engineering and Mining Journal*, Vol. LXVI

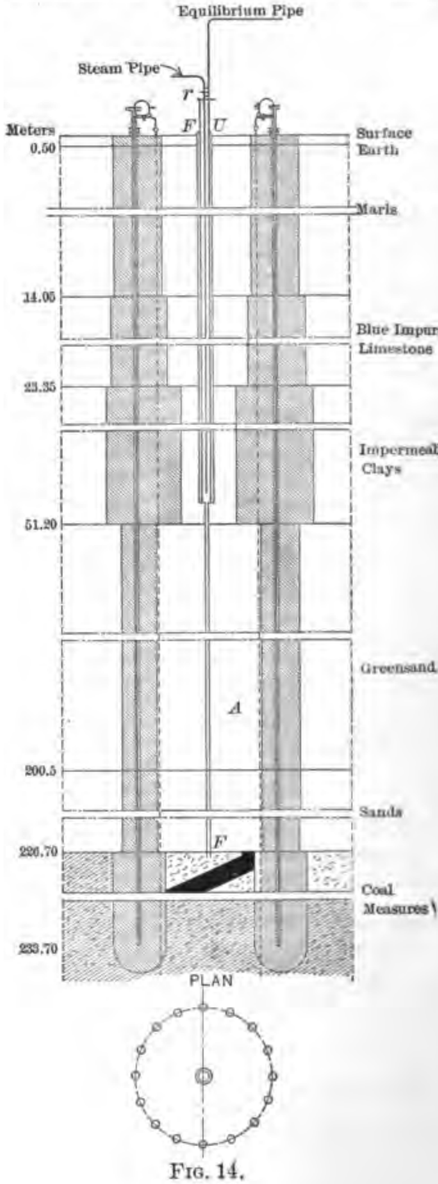


FIG. 14.

The results of some tensile tests. made by Mr. Alby, in France, on ırated sand, are shown graphically in Fig. 13. Tests made at the ıpin Mine (temperature not recorded) gave average results as ows:

Tensile strength, 431 lbs. per square inch.

Compressive strength, 575 lbs. per square inch.

Experience has shown that it is desirable to preserve an unconled core in the center of the shaft, as excavation is facilitated atly thereby. Care must be taken, however, that the annular ice l is carried well below the water-bearing material, or else the lower of the cylinder must be frozen solid. The latter can be accomshed by the insulated central tube mentioned previously and illused in Fig. 11.

Form and Required Thickness of Ice Wall.—Theoretical discussions the form and required thickness of the ice wall are given at conerable length in the *Annales des Mines,** and in the *Bulletin de la iété de l'Industrie Minérale.*†

Lack of knowledge, as to the pressures to be sustained, the strength the frozen material, the conductivity of the various strata, etc., ders the results of analytical study of doubtful value.

Saclier and Waymel, Engineers of the Vicq shafts, state that the ezing pipes should be placed on a circumference of 2 ft. greater ius than that of the excavation. This statement appears to repret practice fairly. Excavation is seldom started until the ice wall hick enough to encroach on the area to be excavated, and, accordly, the thickness is rarely less than 3 ft.

It was formerly believed that the form of the wall was that of a ncated cone with its greater diameter at the base.

Observations have shown that the frozen mass may assume any of following forms: A truncated cone with the largest diameter at bottom; a truncated cone with the largest diameter at the top; a inder; a series of cylinders of varying diameter; a barrel shape.

The base may be either flat, concave or convex.

Time Required for Congelation.—This varies greatly with the nature the material and the thickness of the ice wall. For twenty-one kings, of which the data are available, the minimum initial freezing

* For the year 1885, p. 111; 1887, p. 56; 1900, pp. 379–486.
† For the year 1895, p. 278.

period was 15 days, the maximum 365 days, and the average 94 The initial freezing period covers the time from starting the ic chine to beginning excavation. Congelation is commonly cont until the shaft is completed. During the latter period, howeve full capacity of the machine is seldom required.

Excavation.—Ordinarily, the frozen material is about as diffic excavate as soft sandstone. Formerly, it was excavated entire the use of picks, wedges and chisels. More recently, compr powder, dynamite and gelignite have been used in several instar

Apparently, the use of explosives has not caused any dama the ice wall, but some breaks in the freezing tubes have been a uted thereto. In drilling the frozen material, brine must ofte used, as water freezes and holds the drills fast in the holes.

Lining.—Timber, masonry and iron are commonly used fo lining. Timber and iron linings are usually backed with con In most cases it has been found necessary to add some substa the mortar to prevent injury from freezing.

Mr. M. F. Schmidt* states that when iron lining is used, in to avoid undue contraction and expansion due to extreme chan temperature, it is well to protect the lining by placing betw and the ground some non-conductor, such as wood, straw or g charcoal. As to masonry, it is desirable to use a mortar mixe salt water and pitch, and, moreover, to insulate the lining wooden sheathing. From the information at hand it does not a that the insulation has been used in many cases.

Subway Work or Tunneling.—Figs. 2 and 3 illustrate the m suggested by Gobert and others for applying the freezing proc the construction of tunnels. Thus far, however, no actual tri been made.

Gobert Process.

This process was invented by A. Gobert. The details have worked out quite carefully, and a great deal has been written the system, but, as far as the writer can learn, it has never bee plied in practice.

The essential difference between the Gobert and Poetsch sy is in the medium used for cooling the ground. Gobert disp

* *Bulletin de la Société de l'Industrie Minérale*, 1895, p. 273.

GOBERT PROCESS.

From *Transactions* of the Federated Institution of Mining Engineers, Vol. XI.

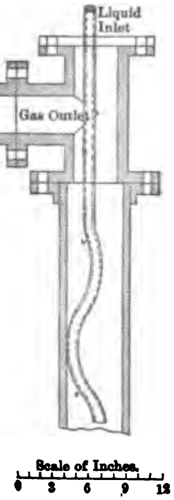


FIG. 15.

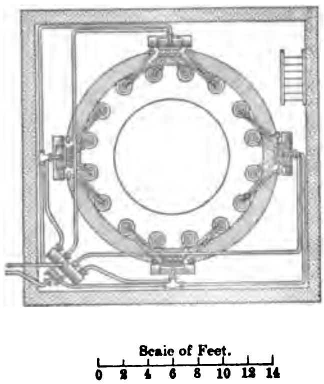


FIG. 19.

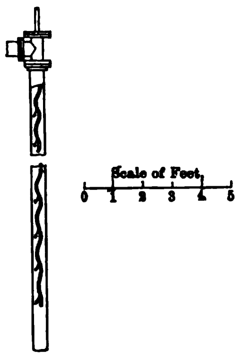


FIG. 16.

FIG. 17.

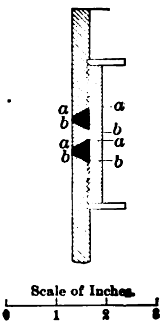


FIG. 18.

with the refrigerator and cooling brine, and allows the liquefied ammonia to expand in the freezing tubes themselves. Some modifications of the fittings are required, principally in the circulating tubes. If the liquid ammonia were allowed to pass directly to the bottom of the freezing tubes it would collect there, and its evaporation would be very slow. Spiral tubes, perforated at frequent intervals, are proposed, to allow the escape of the liquid for the full height of the material to be frozen. Some of the fittings invented by Mr. Gobert are shown in Figs. 15, 16, 17 and 19.

One of the main advantages claimed for this system is that there is no tendency for the freezing medium to escape into the ground to be frozen.

In the Poetsch system, the pressure at any point in the freezing pipes must be equal to the weight of the column of brine above that point. This is always greater than the pressure on the outside of the tubes. In the Gobert system, there is only the pressure of the expanded gas, which is always less than the outside pressure. Accordingly, if breaks occur in the freezing pipes, the leak will be inward instead of outward.

Koch Process.

The writer has been unable to find any very complete description of this process. It involves the direct use of the liquefied gas in the freezing tubes. The gas used may be either carbonic acid, ammonia or a mixture of dioxide of sulphur.

The freezing tubes are divided into various compartments to facilitate expansion. It is claimed: First, that a uniformly distributed temperature of —50° or —60° Cent. is obtained; second, that this low temperature is produced as soon as the machine is started, and, therefore, the freezing tubes contract to the full extent before they are frozen in place, there would be no tendency to rupture the pipes, as in the Poetsch process, where the reduction of the temperature is gradual; third, that the time required for congelation is reduced one-half. The freezing machine and connections are shown in Fig. 20.

From the information at hand, it appears that this process only differs in detail from that of Gobert, but Louis Gebhardt is quoted as

KOCH PROCESS.

From *Gluckauf.* 1895.

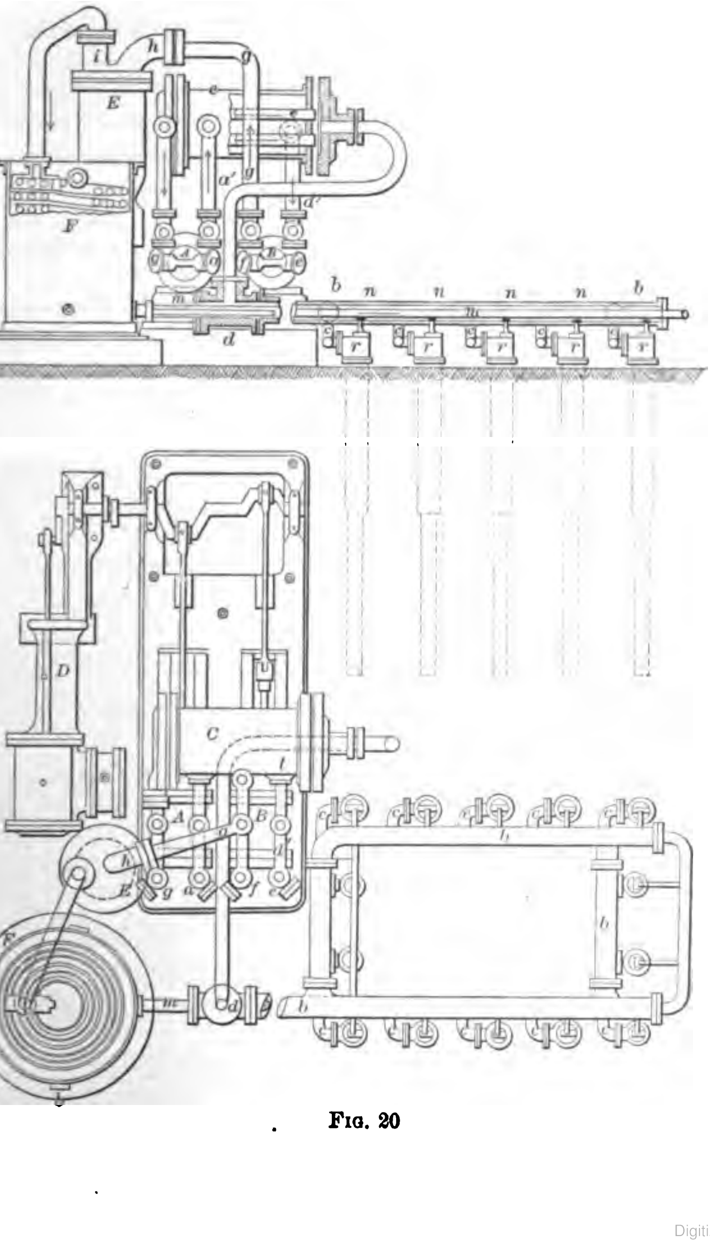


Fig. 20

saying: "The Koch process will solve all difficulties met in actual practice." No accounts have been found of any actual application of the system in sinking a shaft or driving a tunnel.

Freezing by Cold Air.

The only direct application of cold air that has been found was at Stockholm, and that is described under the head of the Stockholm Tunnel. This is also the only case found where the freezing process has been applied to tunnel work.

Application of Freezing Processes.

Archibald Shaft.—This shaft belongs to the Douglas Company, and is located at Schneidlingen, Saxony. This was the first practical application of the Poetsch process. The work was done during the year 1883. A shaft, 15.4 x 10.3 ft., was sunk to a depth of 111.5 ft. through solid and fairly compact measures by pumping. At this depth very watery quicksand was encountered. A bore-hole was put down, through the quicksand and underlying measures, into a previously existing heading of the mine. The object of the bore-hole was to drain the quicksand, and a considerable flow of water was set up through the channel. Sinking was then resumed by means of sheet-piles, but, after an advance of 4.3 ft., the work had to be abandoned, and it was turned over to Mr. Poetsch. The material to be congealed consisted of 18 ft. of quicksand. Twenty-three wrought-iron tubes were put down through the quicksand and 1 ft. 7 ins. into the lignite. Owing to the difficulty of enlarging the shaft, all the freezing pipes were placed inside the area to be excavated; ten of them were placed close to the sides of the shaft. Their arrangement is shown in Fig. 21. The pipes were 8 ins. in diameter, and were closed at the bottom by inserting wooden plugs. The plugs, in turn, were covered with 2 ins. of cement and 2 ins. of plaster and clay. The inner or circulating tubes were about 2 ins. in diameter. The distributing and collecting rings were placed at the level of the top of the freezing tubes, or 111.5 ft. below the surface.

A Carré-Kropff machine, capable of producing half a ton of ice per hour, was used for freezing. The freezing solution was chloride of calcium. To observe the progress of congelation, twenty small pipes,

ns. in length, were sunk into the quicksand and filled with a solu- of chloride of calcium. Inside these pipes thermometers were ced.

Table No. 1 shows the temperature at various points in the shaft he beginning of the freezing process and at the end of the initial zing period.

TABLE No. 1.

	July 8th.	July 31st.
perature of air at bottom of shaft............	+ 58.6° Fahr.	21.2° Fahr.
" " ground, east side...............	51.8 "	— 2.2 "
" " " south "	51.8 "	— 0.5 "
" " " west "	51.8 "	— 2.2 "
" " " north "	51.8 "	— 0.4 "

The temperatures of the ground at the sides were taken as near as ible to the freezing tubes. Owing to the fact that the upper ends he freezing pipes were 4.3 ft. above the quicksand, there was con- rable loss by radiation. The stream flowing through the center of shaft also had the effect of warming up the freezing solution and tarding the progress of congelation. Fifteen days after the freez- machine was started, the ground over the entire area of the shaft, about 30 ins. outside, was frozen solid.

small shaft was first excavated to the coal. This shaft was tim- d, temporarily, every 3 ft. Coal was reached on September 30th. rgement of the shaft to full size was then started at the bottom, uncovering all the freezing tubes. It was found that radiation the pipes could not be depended upon for maintaining the ice wall e exposed pipes were coated with hoar frost rapidly. Excava- had to be suspended until the wall had attained such a thickness it would not be in danger of thawing out during the remaining ations. Excavation was carried on by means of picks, no powder g used. The shaft was perfectly dry, and the soil was as hard as stone. It was worked by means of picks, wedges and mauls. temperature at the bottom of the shaft, while the sinking opera- s were in progress, varied from 0.5° to 1° Centigrade. The men not suffer any bad effects from the cold. The permanent lining of shaft consisted of timber cribs. It is stated that perfectly dry per must be used, as frost is likely to shatter green or wet timber.

The following table of costs of the different operations is attrib
to the manager, Herr Frohberg:

Placing pipes..................................	$978.17
Sinking (131.2 ft.)..............................	583.98
Lining..	851.64
Congelation (100 days)........................	900.30
Interest on capital and sinking fund..........	3 649.88
Carriage of plant................................	973.30
Erection of plant................................	1 751.94
Superintendence and traveling expenses......	1 800.60
Total..	$11 489.81

Michalkowitz Colliery.—The Max workings are located at L
Hütte, Province of Silesia, Germany. Sinking by freezing was
at this shaft during the year 1884. An attempt was made to sink
shafts, 164 ft. apart. The first was excavated to a depth of 213.
by ordinary means. At that depth quicksand was encountered,
work was continued by the use of sheet-piles until the bottom o
pit was 246.1 ft. below the surface. As the water pumped amou
to 205 cu. ft. per minute, work had to be stopped, and the botto
the shaft was closed with a bulkhead, 3.3 ft. thick.

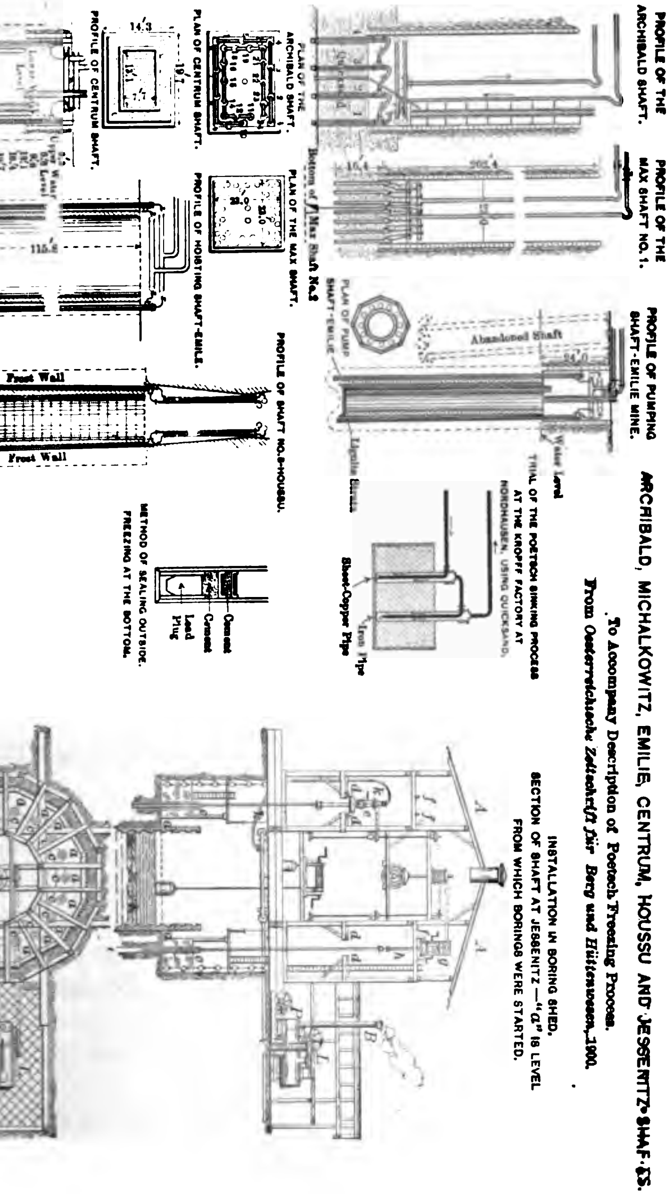
The nature of the material is shown by the following:

Alluvial sand..........	45.9 ft.	Hard shell lime........	62.
Clay (little water)......	62.3 "	Variegated sandstone..	91.
		Total	262.

At this depth coal was reached.

The shaft was square in plan, 22 ft. 11 ins. on a side.

Forty-two freezing pipes, of 8 ins. inside diameter, were put
in the bottom of the shaft. The manner of placing and conne
the tubes is shown in Fig. 21. The tubes were given a slight inc
tion outward, and, at their lower ends, were provided with a sho
for receiving a lead plug. On attempting to place the lead plu
was found that the pipes were not all of the required diameter,
moreover, some of them had assumed an elliptical form unde
pressure of driving. Under these circumstances, there was a
deal of difficulty in closing the ends. After congelation was sta



ARCHIBALD, MICHALKOWITZ, EMILIE, CENTRUM, HOUSSU AND JESSENITZ SHAFTS.
To Accompany Description of Poetsch Freezing Process.
From *Oesterreichische Zeitschrift für Berg und Hüttenwesen*, 1900.

it was found that eleven pipes leaked. Smaller pipes, closed at t lower ends, were placed inside the defective tubes, and operat were resumed.

A Carré-Kropff machine, capable of making half a ton of ice per h was used for congelation. After the measures had been cooled to Cent., the machine broke down, and freezing was stopped for a w During this delay the ground resumed its original temperature. M while, the owners of the colliery had proceeded with the second sh without encountering as much difficulty as in the first.

When they reached a level lower than the bottom of Shaft N the water was drawn from the first shaft, and there was no longer need for the freezing process. Soon after this the time limit, u which Mr. Poetsch had contracted to complete the freezing, expi The temperature of the measures was still at + 1° Cent., and attempt at congelation was discontinued. The failure at this poi attributed to delays due to the timber in the shaft and the accid to the plant itself. It is claimed, also, that the pumping from second shaft retarded the freezing.

Emilie Colliery, Pumping Shaft.—This colliery is located near sterwald, Brandenburg, Prussia.

The sinking by the freezing process was commenced in 1884 completed in 1885. An attempt was made to sink both the pum and the winding shafts by ordinary means, but both failed and were filled up. The freezing process was then adopted, but sites were chosen.

The material penetrated was as follows:

Yellow sand............	3.3 ft.	Rough gray sand, very aquiferous...........	19.
Fine white sand........	6.6 "	Coarse gray sand.......	21.
Coarse gray sand	11.5 "	Fine gray sand.........	11.
Coarse gravel..........	3.9 "	Fine brown sand........	13.
Dry, rough sand	7.5 "	Total..............	125.
Damp, rough sand.....	26.3 "	Lignite............	14.

The strata are all very aquiferous. The natural ground-w level was at a depth of 29.5 ft.

The shaft has a clear diameter of 8.8 ft.

A square pit, 16.5 ft. on a side, was sunk to a depth of 26 ft., and rom the bottom twelve borings were made on the circumference of a ircle having a diameter of about 14 ft. The bore-holes were inclined lightly outward. The linings of the bore-holes, plugged at their ower ends with lead and concrete separated by iron washers with ubber joints, served as the freezing tubes. The depth of the pipes aried from 125.5 to 128 ft., and the penetration into the lignite from .7 to 3.1 ft. The relative positions of the old and new shafts, as well s the arrangement of the freezing tubes, are shown in Fig. 21. It was ound that Hole No. 2 varied too much from the perpendicular, and wo more holes were put down to take its place. This work was not ompleted until congelation had been begun.

A Carré-Kropff machine, having a capacity of half a ton of ice per our, was used. The freezing solution was calcium chloride. The achine was running regularly by June 25th, and on August 8th the ower was formed, except near Holes Nos. 1 and 2. Sinking was arted before this gap was closed, but water came in, stopping the xcavation. Attempts to continue by pumping weakened the ice all, but, on September 8th, it was sufficiently strong to allow the esumption of excavation.

The shaft was lined with timber temporarily, and, on October 31st, ne coal seam was reached. It was found that the center was not ozen, the congealed matter having taken the form of a bottle. efore the temporary lining could be completed, water burst in, and ne bottom was filled with gravel. By continuing congelation the ak was stopped. Timber cribs were inserted next, near the top of ne lignite, forming the base for the permanent masonry lining. On ovember 20th, when the height of the permanent lining was 16.4 ft., ne machine was stopped for four days, when the ice wall gave way nd sandy water rose between the masonry and the sides of the pit. his leak was checked by starting the machine, but, on December 5th, a fresh inburst occurred. It was found necessary to fill the naft with ice and snow, after which the walls were congealed thorughly in a short time. The lining was completed about April 1st, 885. Most of the trouble with the ice wall is attributed to starting ne excavation before the congelation had been completed, and to the act that the pipes were not sunk deep enough into the coal.

The cost is summarized as follows:

Allowance for interest and cost on plant, 25 per cent. of $14 610	$3 652.50
Cost of carriage of plant	974.00
Erection and establishment	4 675.20
Use of freezing machine two hundred and forty days	2 834.34
Sinking and lining	1 850.60
Superintendence, etc.	1 860.34
Total	$15 846.98
Cost per foot	$126.80

Emilie Colliery, Winding Shaft.—This shaft was located 147.6 from the pumping shaft. It was built during the year 1885.

A rectangular shaft was sunk by ordinary means to a depth of 3 ft., or about 3 ft. below the water level. Below this depth, the sh is an ellipse having a major axis of 13 ft. 2 ins., and a minor axis of ft. 1 in. A plan and vertical section are shown in Fig. 21. Sixte refrigerating pipes, about 1 m. apart, were put down surrounding t ellipse. The total depth of the holes varied from 117.3 to 121.4 f and the penetration in the lignite was from 1.0 ft. to 3.8 ft. Sinki was begun on June 11th, 1885, and had reached a depth of 94.3 ft. August 15th, when it was found that some of the pipes were not tight the bottom. Excavation had to be suspended until October 9th, to e able fresh plugs to be put in. Near the bottom of the shaft the ice w gave way on several occasions, and the pit was filled partially wi sand. The lignite was reached on November 5th, and shortly aft ward the masonry lining was started. The mortar in the lining w prevented from freezing by steam led through a copper pipe. T lining was completed on December 12th, 1885. Borings showed t thickness of the ice wall to be 2 ft. or more down to a depth of 98 At that depth it decreased to 10 ins. quite suddenly on one side, a water and sand burst into the shaft. The decrease in thickness w attributed to leaking pipes. The cost per foot averaged about $101.

Centrum Colliery.—This colliery is located at Köningswursterhause Brandenburg, Prussia, and is owned by Dr. W. Siemens.

Most of the work was done during the year 1884. An attempt w

ade to sink the shaft by pumping, but this method had to be bandoned at a depth of 52.5 ft. The Poetsch process was then lopted.

The material through which the shaft was sunk is as follows:

ellow sandy clay	14.7 ft.	Coarse sand	2.1 ft.
ray sandy clay	6.6 "	Sandy clay	13.9 "
ray sand	0.5 "	White quartzose sand ...	54.0 "
andy clay	13.0 "	Total	104.8 ft.

The ground-water is at a depth of 14.8 ft.

For a depth of 19.7 ft. the old excavation was enlarged to a rect-ngular section, 14 ft. 2 ins. x 19 ft. 8 ins. Below this depth the shaft as also a rectangle, but only 13 ft. 1 in. x 7 ft. 7 ins. Fig. 21 shows plan and vertical section.

At the bottom of the enlarged shaft, sixteen freezing pipes, four on side, were put down parallel to the sides of the small shaft and out-de its area. The freezing pipes were 7 ins., outside diameter, and [illegible] in. thick, and their bottoms were 106.6 ft. below the surface of the round. The lower ends were closed with lead plugs. The 7-in. pipes nded a short distance above the bottom of the enlarged shaft, and ere connected with the collector ring, which was above the surface of he ground, by smaller bent pipes.

Congelation was started on April 14th, and sinking on June 8th. uring the greater part of this time, the water stood in the shaft at its atural level.

The ground in the middle of the shaft was thawed by steam, and y this means was formed a shaft the sides of which were attacked by icks. When the excavation had reached a depth of 52.5 ft., a break the ice machine caused a suspension of congelation for a month.

The surface water flowed down over the frozen wall and raised the emperature to +10° Centigrade. Accordingly, the work of sinking as stopped and the shaft filled with water. Two weeks after the achine was started, excavation was again resumed, and the coal was eached on October 11th. The daily progress was about 2.8 ft.

The timber lining was completed, except the last crib at the bot-om, when a bore-hole was put down into the lignite which was found be frozen to a depth of 110.9 ft. below the surface of the ground. n the following day, water burst into the shaft, through the bore-

hole, and enlarged the channel rapidly. The shaft was pumped out on several occasions, but the lining was not completed. A second accident to the ice machine added to the difficulties, and, finally, a plug at the bottom of one of the freezing pipes blew out, allowing the liquid to escape. The latter accident made the completion of the lining impossible. The shaft, however, was used for pumping purposes for a couple of years, or until the mine was abandoned for reasons not connected with this shaft.

The cost is stated by Mr. Poetsch to have been $162.00 per foot.

The failure to complete this shaft satisfactorily is said to have been due to not sinking the freezing tubes far enough into the lignite, and to delaying the completion of the lining.

Stockholm Tunnel.—This tunnel is in Stockholm, Sweden, and was built during the years 1884 to 1886, inclusive.

It was designed and built by Captain Lindmark. The object was to afford easy communication for pedestrians between two parts of the city separated by the ridge, a cross-section of which is shown in Fig. 24. The eastern end of the tunnel, being mostly in rock, was constructed in the usual manner, and caused little trouble. At the west end the Rziha system was at first adopted. The iron wall shown in Figs. 26, 27 and 28 was also devised for supporting the face. After an advance of 40 ft. by the above means, a considerable subsidence had taken place, and work had to be discontinued. Captain Lindmark then decided to freeze the earth before proceeding farther.

The tunnel is 12 ft. 8 ins. high and 13 ft. 2 ins. wide. The cross-section is shown in Fig. 25. The length is 758 ft. Fig. 22 is a plan of the work, Fig. 23 is a cross-section, and Fig. 24 is a profile of the street and tunnel. The relation of the rock and earth is shown clearly by the profile. The rock was granite. For the first 120 ft. from the west end, the material consisted of coarse gravel intermixed with large stones and a small quantity of wet clay. On account of the water it contained, this material had no cohesion whatever, and would run through a very small opening. The remaining portion of the tunnel, before entering the rock, penetrated pure sand possessing considerable cohesion.

For freezing the earth, a Lightfoot dry-air machine was used. It was capable of delivering about 25 000 cu. ft. of air per hour. The air left the machine at a temperature of —55° Centigrade. The

TUNNEL FOR FOOT PASSENGERS, STOCKHOLM.

From *The Engineer*, London.

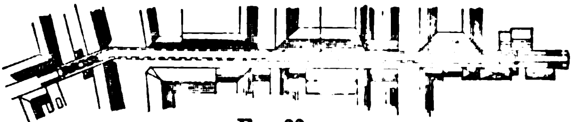


Fig. 22.

23.

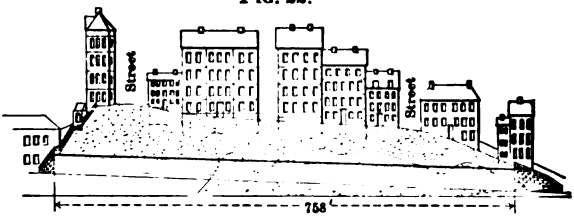
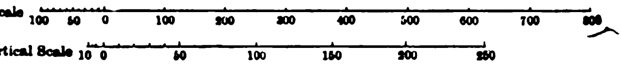


Fig. 24.



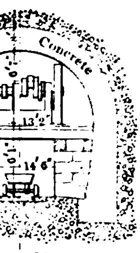


Fig. 25.

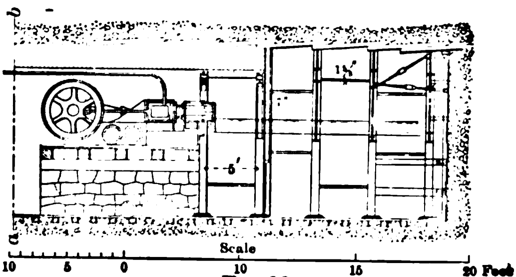
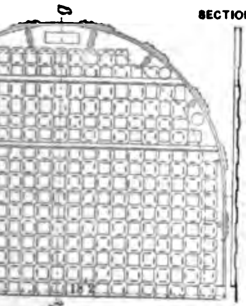


Fig. 26.



G. 27.

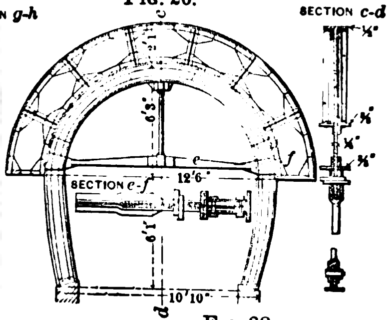
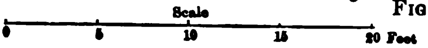


Fig. 28.



machine was erected as close to the heading as practicable, a freezing chamber was formed by partitioning off the heading. partition was movable and consisted of a double wall of plank filled with charcoal. After the machine had been discharging air into the freezing chamber for sixty hours, it was found that surrounding material had been frozen to depths varying from 5 f the bottom to 1 ft. near the top. At the crown no freezing took pl The temperature at the bottom was as low as —40° Cent., but tha the roof remained steadily at 0° Centigrade.

Excavation was started at the top, the roof being supported poling boards driven into the uncongealed material at the cro This soft material was considered an advantage, as it is said the would have had to be supported in any event, and the driving of poling boards was made much easier thereby. The heading was vanced in lengths of 5 ft., and the face was supported by the iron built from the top downward to within about 8 or 9 ft. of the fl The material was so solid that it was not found necessary to sup the lower portion of the face. After the first, the freezing mac was only run from 10 to 12 hours during the night. At the end of t time the temperature was from —20° to —25° Cent., but soon after workingmen entered it rose to zero. After heavy rains it was ne sary to run the machine somewhat longer. When two sections been completed, the partition was moved forward. The size of freezing chamber varied from 3 000 to 6 000 cu. ft. A length of abou ft. of tunnel was constructed by this means. The material then bec sufficiently firm to allow the excavation to proceed without freez The rate of progress while congelation was used was about 1 ft. day.

The lining was built as rapidly as possible after the partition been moved forward and while the ground was still frozen. The c crete used was composed of 1 part of Portland cement, 2½ part sand and 6 parts of granite. The lining did not appear to suffer injurious effects from the frozen material behind it.

No subsidence took place on the north, but the house on the so settled about 1 in., producing some small cracks.

Houssu Colliery, Pit No. 8.—This colliery belongs to the Soc Anonyme des Charbonages de Houssu, and is situated at Haine-S Paul, in the Province of Hainaut, Belgium.

The Poetsch process was adopted in 1885, and the work was not ompleted until near the end of 1887. At first, an attempt was made sink by pumping, as a bore-hole, some 50 ft. away, did not disclose ny unusual difficulties. At a depth of 82 ft. a stream of water, yield-g about 7.3 cu. ft. per minute, was encountered, but the pumps were ble to handle this amount. When the bottom of the pit had been rried down to a depth of 196 ft., and, while excavating in hard marl, uicksand and water burst in through the floor. The water rose to a oint 82 ft. below the surface, and the lower portion of the excavation as filled with quicksand to a height of 20.3 ft. The thickness of the lid marl through which this inrush took place was determined fterward to have been 4.9 ft. Attempts to take out the water and pro-eed with the excavation were without result, and, as the best means or saving the work done, the freezing process was adopted. The shaft circular, and its internal diameter is 13 ft. 1 in. There is some onflict as to the nature of the material which was to be congealed.

The following represents its nature approximately:

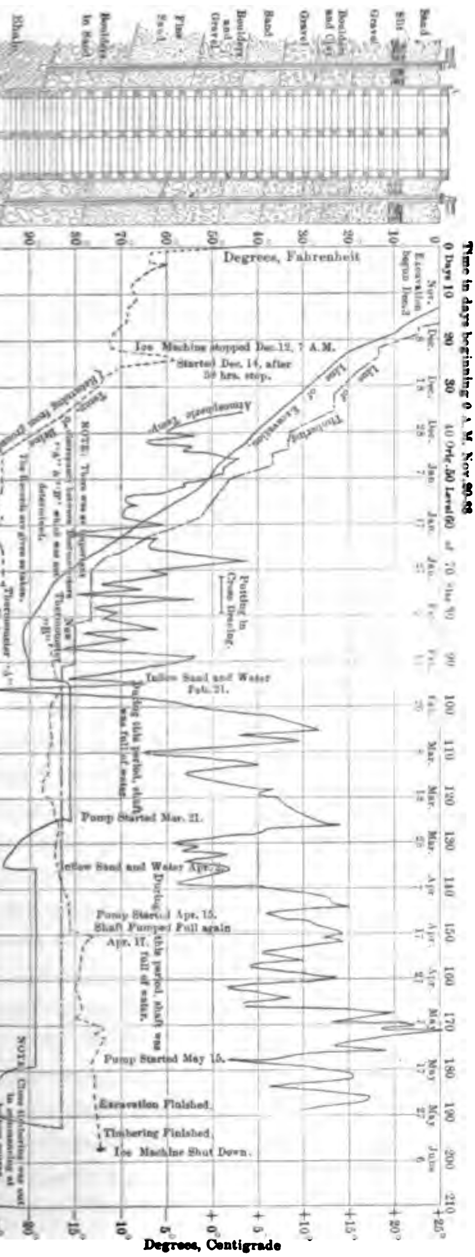
and which had flowed into the pit	19.7 ft.
lard marl	4.9 "
and, with pebbles	15.1 "
lack sand, with traces of clay	1.0 "
rgillaceous sand	0.9 "
andy clay	2.3 "
onsistent gray plastic clay	1.2 "
lack sand	0.5 "
reen gravel, with shells	0.5 "
Sand, with pyrites	1.6 ft.
Black sand, with lignite and shells	5.8 "
Black sandy clay, pebbles, pyrites and lignite	1.3 "
Fine-grained black sand	1.3 "
Black earthy and sandy clay, with pyrites and fossil wood	3.3 "
Black argillaceous sand, with pyrites	2.0 "
Total	61.4 ft.

After clearing the water from the pit, its size was increased grad-ually from the depth of 144.3 ft. to that of 177.2 ft., so that its diame-er at the latter depth was 19 ft. 8 ins. From the ledge thus formed, n the circumference of a circle having a diameter of 16.79 ft., ighteen freezing pipes were put down. The bottoms of the tubes ere at a depth of 246 ft. below the surface, and, therefore, they were 39 ft. long. The outside or freezing tubes were 6 ins. in diameter, and he inside or circulating tubes 2 ins. The boring for and placing of

tubes occupied five and a half months. The circulating and return rings were placed near the level of the bench, and were connected with the freezing tubes in the usual manner. A single well-lagged pipe led from each of the rings to the cooling apparatus, thus completing the circuit. The arrangement of the tubes is shown in vertical section in Fig. 21.

Congelation was started on December 12th, 1885, with a Carré-Kropff machine capable of producing about 900 lbs. of ice per hour. After six months, the temperature of the sand was found to be at 0° Cent., and it was not sufficiently solid to allow the work of excavation to be begun. Mr. Poetsch attributes the inefficiency of the first machine: First, to its distance from the freezing tubes, 177.1 ft.; and, second, to the influence of the warm water said to come from the condenser of a 200-H.-P. engine at another shaft. He estimates that these two sources absorbed at least 50% of the output. The water had been allowed to stand at its natural level, 82 ft. below the surface.

By the advice of Mr. Poetsch, the pit was kept dry by pumping, and the capacity of the freezing plant was doubled, but about five months more elapsed without result. Mr. Poetsch then discovered that one of the freezing pipes was broken, allowing the uncongealable liquid to escape, and, also, that the large quantity of water pumped had a temperature of 11° or 12° Centigrade. The broken tube was repaired and pumping stopped. The freezing of the ground was then completed successfully in four weeks. The process of congelation consumed one year. The freezing liquid was a solution containing about 23% of calcium chloride. During the latter part of the process the temperature of the liquid on leaving the machine was about —25° Cent., and on returning it was about 4° higher. Sinking was carried on by means of picks and wedge needles. A shaft, about 11 ft. square, was put down to the coal first, by gangs of four men working in 6-hour shifts. After excavating a depth of 8 ft., temporary timbering was put in and excavation resumed. The rate of progress was about 1 ft. 7 ins. per day. An attempt was made to thaw the earth by means of steam. Five cylinders of plate iron, 3 ft. 3⅝ ins. high and 2 ft. 7 ins. in diameter, were placed on the shaft floor. The cylinders were open at the bottom, and steam was admitted at the top. This apparatus was too cumbersome, and, besides, it produced a mud that was very disagreeable to work in, and its use was soon abandoned



PROGRESS DIAGRAM OF SHAFT SUNK AT CHAPIN MINE IRON MOUNTAIN, MICHIGAN, BY THE FREEZING PROCESS.

From School of Mines Quarterly, Vol. XI.

After the completion of the advance shaft, it was enlarged from the bottom up and the shaft lined with cast iron, 1½ ins. thick. The iron lining was backed with concrete. The cement was found to set satisfactorily. Sea salt was added to the mixing water at first, but was found to be unnecessary. The iron lining was carried up to the base of the old work, where it was joined with a masonry lining placed previously.

At the depth of 177 ft. below the surface, work on the lining was suspended to allow the removal of the freezing tubes. On February 14th, 1888, about two months after congelation had been stopped, quicksand burst into the shaft through one of the holes from which the freezing pipe had been withdrawn. Work was at once resumed on the lining, and the remaining tubes were left in place.

Shaft at Chapin Mine.—This shaft is at Iron Mountain, Michigan. The contract for the work was let in 1887, and the shaft was completed in the early part of 1889.

The Chapin Mining Company found it advisable to locate a shaft near the center of a small valley crossing its property. Previous attempts to sink by ordinary means had failed, and a contract was made with the Poetsch-Sooysmith Freezing Company, to sink by the Poetsch system.

The rock and ore beds approached the surface on both sides of the valley, but dipped down under the center, and, at the point where the shaft was located, they were covered by about 95 ft. of loose material. The overlying formation was sand interspersed with layers of gravel and boulders. Many of the boulders were of large size and were packed so closely that they had the appearance of having been laid by a mason. The sand, which was fine, had a little clay mixed with it, and was very unstable. The miners said: "It will run where water will." The level of the ground-water, originally, had been close to the surface in the center of the valley, but pumping at other points had lowered it to a depth of about 10 ft. at the shaft.

Careful experiments showed that the fine sand contained about 17% of water; the proportion in the other materials was not nearly as great. The relations of sand and boulders are shown in Fig. 29. The shaft, originally, was intended to be circular, but was changed to a rectangular form, 15½ x 16½ ft.

The freezing tubes were placed on the periphery of a circle, 29 ft.

diameter. Mr. Moran and *Engineering News* state that twenty-six pes were used, while Mr. Abbott gives their number as twenty-seven. ie bore-holes were cased with 10-in. pipes, and great difficulty was und in keeping them plumb, particularly in passing through the ulders. As soon as the casings had penetrated the ledge, 8-in. ezing pipes were lowered into place and the casings withdrawn. ie freezing tubes had flush joints, both inside and outside, were ⅜ in. ick, and varied in length from 87 to 97 ft. The joints were tested der heavy pressure as the pipe was lowered into position. The ner tubes were 1¼ ins. in diameter. The fittings at the top of the ezing tubes are shown clearly in Fig. 1.

A Linde machine, having a refrigerating capacity of 50 tons daily, s used for congelation.

The motive power was an Allis-Corliss engine using compressed air 60 lbs. pressure and developing 55 H.-P. at sixty revolutions per inute. The freezing medium was a 25% solution of the ordinary loride of calcium of commerce. About 200 cu. ft. of brine were used, d made a complete circuit every 33 minutes. The temperature of e brine on returning from the tubes is shown graphically in Fig. 30. is diagram also shows the temperature of the atmosphere, which d a very considerable effect on the condensing water used for lique-ing the ammonia. The temperature of the brine, as it entered the bes, was about 1° Cent. lower than on returning to the cooling tank. test pipe midway between two freezing tubes was frozen on the sixth y after the refrigerating machine was started, and a second pipe, 5 3 ins. inside the circle of congelation tubes, was frozen on the enty-first day. Tests of the frozen sand gave an average tensile rength of 431 lbs., and a corresponding compressive strength of 575 s., per square inch.

Excavation was started fifteen days after the refrigerating plant s put in operation. On the twenty-third day after freezing began e machine had to be stopped, as the supply of compressed air iled. Congelation was suspended for 60 hours; consequently, exca-tion and timbering were stopped until the twenty-eighth day. From is time until the ninety-third day, excavation was carried on without y interruption, except for placing timber. For the last thirty days, ater had been coming up through the uncongealed core. The water mained clear until the ninety-third day, when it increased in vol-

ume, and sand began to come with it. As the volume of both sand and water increased rapidly, the shaft was at once filled with water, in order to equalize the pressure and thus prevent further flow. An additional freezing pipe was put down, and the leak was closed. On the one hundred and thirty-fifth day, when the bottom of the pit was 7 or 8 ft. in the rock ledge, water and sand again burst into the shaft along the upper surface of the ledge. The water, apparently, finding its way through fissures in the unfrozen rock ledge, had eventually warmed up the rock enough to thaw the joint between the ledge and the sand. As soon as this joint was broken, the water pressure was sufficient to force a current through and disintegrate rapidly the lower portion of the ice wall. It was necessary to flood the shaft again, but, before doing so, a coil of pipes was suspended against the wall near the leak.

This coil was connected with the ice machine, and served effectually to shut off the leak. Excavation was carried on with picks and chisels, and perhaps by the use of explosives. There is a conflict of statements on the latter point. Mr. Thomas states that heavy charges of dynamite were required, while *Engineering News*, in its description, says black powder was used for a time, but was discarded finally, for fear of its effect on the walls.

No temporary lining was used, but the placing of the permanent wooden lining followed the excavation closely. Heavy cross-timbers were set across the top of the shaft, and a rectangular crib was suspended by means of eye-bolts Other cribs were placed as the work progressed, each suspended from the one above. The cribs were sheathed with planks placed as closely together as possible. The joints between the planks were water-proofed with strips of tar paper dipped in hot pitch and held in place by battens. Wedges were driven between the lagging and the ice wall to hold the lining in true position, and the space outside the latter was filled as completely as practicable. The joint between the lining and the ledge was made by fitting the timbers to the rock surface carefully and then grouting around them with cement mortar. The lower 15 ft. of lining was close timbered. The construction of the lining is shown clearly in Figs. 31 to 34, inclusive. The progress of both lining and excavation is illustrated graphically in Fig. 30.

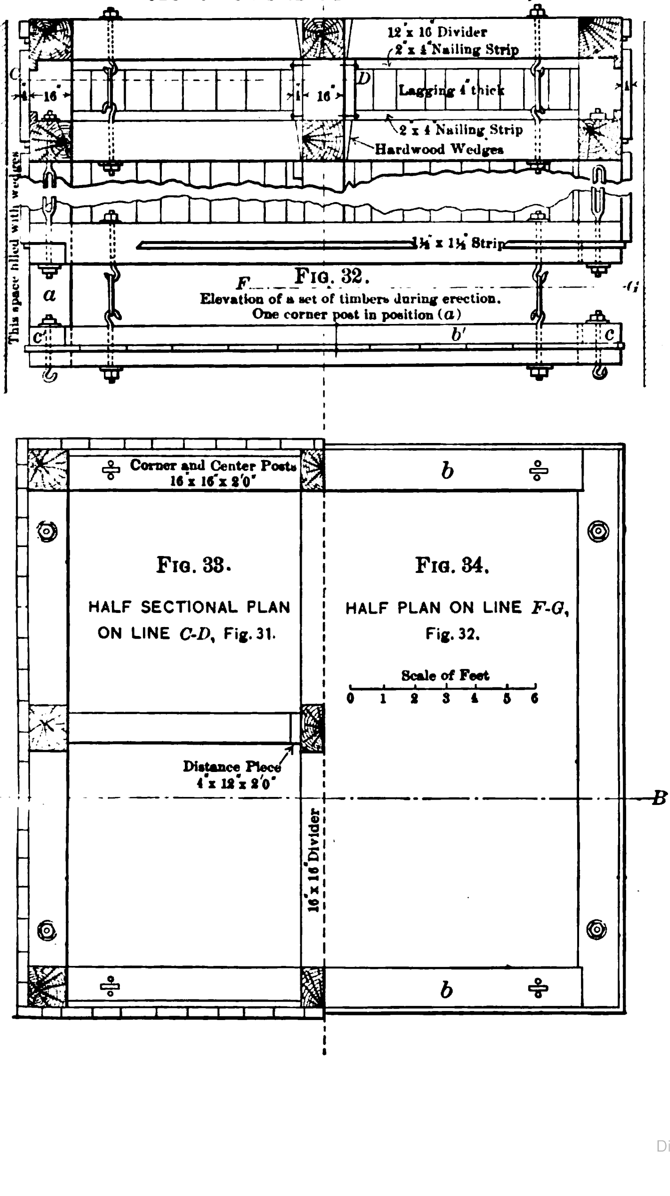
After the completion of the work, in order to test the thickness of the ice wall, a pit was sunk in the outer edge of the wall for a

PLANS OF LINING. CHAPIN MINE.

From *School of Mines Quarterly*, Vol. XI.

FIG. 31.

SECTION ON LINE *A-B* COMPLETED SHAFT.



depth of 20 ft., and a steel rod was driven down considerably fur
The wall had a batter of about 1 in 15. The diameter of the ice
at the bottom of the pit was 54 ft. Water did not find its way thr
the ice wall until fifty days after shutting down the refriger
plant.

The alignment of the lining was not disturbed by the meltin
the ice wall.

Jessenitz Mines.—These mines are near Lübtheen, in Mecklenl
Schwerin.

Work, by the congelation process, was commenced in 1887,
abandoned about 1891. The shaft was not completed until
When the work was started, it was decided to sink through the
262.5 ft. by congelation; below this depth, it was thought the mea
were so compact that ordinary means would suffice. The plans
carried out successfully to a depth of 410.1 ft., when water-be
measures were encountered again, and, as a bore-hole revealed
fact that they extended to a depth of 590.6 ft., the freezing pr
was resorted to again.

Mr. M. F. Schmidt states that the material penetrated in the u
portion of the shaft was as follows:

Yellow sand	39.0 ft.	Blue clay	1.
Gray sand	21.7 "	Gypsum and sand	7.
Gravel	5.7 "	Fissured gypsum	11.
Rough gray sand	32.0 "	Gypsum	34.
Coarse gravel	4.1 "	Alternations of gypsum, clay and limestone	53.
Clay and gravel	6.1 "	Total	227
Fallen-in rocks	4.6 "		
Limestone	5.7 "		

Chief Engineer Riemer gives the following list of the s
penetrated by the various processes:

Sand	62.3 ft.	Gypsum, hard	243.
Mixed gravel, part fine and part coarse	45.7 "	Cavernous gypsum, with clay	12.
Gypsum, with interbeddings of sand	33.0 "	Sandstone, fissured	24.
Gypsum, both hard and soft	82.0 "	Gypsum, with anhydrite	383.
		Total	885.
		Rock salt.	

The ground-water level was 26.2 ft. below the surface.

The shaft was circular, and 16 ft. 4 ins. in diameter. For a depth of 23.0 ft., a well, with a diameter of 30.4 ft., was sunk by ordinary means.

Twenty freezing tubes were put down on the periphery of a circle, 22 ft. 11 ins. in diameter. Sixteen of these holes were more than 230 ft. deep, one was 328.1 ft., and three were 262 ft. deep. Owing to the difficulty of closing the bottom of the casings, a smaller pipe, with its lower end welded and tested to a pressure of ten atmospheres, was placed inside, to serve as the freezing tube. Fig. 21 shows the arrangements for making the borings, as well as the location of the holes.

Congelation was started on July 26th, 1887. After the machine had been working one hundred and eight days, the diameter of the ice cylinder was 29 ft. 6 ins.

Sinking was begun on November 10th, 1887, and completed to solid material on March 14th, 1888.

The shaft was lined with cast-iron tubbing backed with concrete. The lining was completed on July 5th, 1888. Efforts were then made to thaw the ice tower by filling the shaft with water at 60° Cent., and maintaining it at that temperature for two weeks. After emptying the shaft, sinking was continued in the ordinary way to a depth of 410.6 ft., where the water-bearing strata were encountered again. It was decided to sink twelve tubes, on a circle 33 ft. 4 ins. in diameter, to a depth of 623.4 ft. Although eight months had elapsed since the ice machine was stopped, the frozen measures were encountered, and the attempt to sink the tubes in this position was abandoned. Eight pipes were then put down on the circumference of a circle inside the shaft.

It was proposed to sink first a small shaft of the same diameter as the circle on which the pipes were placed, and then enlarge to the required diameter by excavating outside the tubes. Before sinking the small shaft, the ice wall was formed, apparently without difficulty, but, after the pipes were exposed, they were not able to maintain the necessary thickness of the ice. Mr. Schmidt states: "The pipes once exposed did not possess the same radiating refrigerating power, and the loss of cold inside the shaft was enormous."

On January 13th, 1890, at a depth of 492.1 ft., the ice wall gave w and the sand rose 16.4 ft. in the shaft. Freezing was continued f thirteen months without result. The attempt to sink by means congelation was abandoned finally and the Kind-Chandron meth adopted.

The failure of the freezing process during the latter part of t work is attributable partially to pumping, which started an unde ground current containing potash salts. These salts lowered the co gelation point of the material to be frozen.

Georgenberg Mine.—This mine is near Tarnowitz, in Upper Siles Germany.

The sinking was done during 1890 and the early part of 1891.

The object of the shaft was access to a bed of iron ore. Previo to adopting the freezing process, an attempt was made to sink pumping, at a point 328 ft. from the site finally selected, but had be abandoned. The size of the shaft was 9 ft. 10 ins. x 14 ft. 8 ins.

The material to be penetrated consisted of about 78 ft. of tertia strata, described as quicksand, and containing a great deal of wat Underlying the tertiary strata was a bed of limestone.

The boring, freezing and lining required nine months.

No. 10 Shaft, Lens Colliery.—This colliery is at Vendin-le-Viel, I partment of Pas-de-Calais, France.

Most of the work was done during 1891. The first attempt to si was made with a masonry caisson. A masonry tower, 53 ft. high, w constructed on a cast-iron shoe or cutting edge. Excavation was c ried on inside the tower, and the work was kept dry by pumping. T tower stuck fast, finally, at a depth of 41.0 ft. Sinking was then c tinued with sheet-piles to a depth of about 80 ft. At this point t temporary lining gave way, partially; the foundations of the perm nent plant, which had been built around the shaft, began to sett and a 1 000-H.-P. pumping plant was unable to control the wat Under these conditions, preparations were begun to continue the wo by means of congelation. The shaft was circular, with a cl diameter of 15 ft. 8 ins.

The nature of the material, from the surface down, is shown the following:

getable earth	1.6 ft.	Yellowish chalk	3.9 ft.
ay, with shifting marl	2.6 "	Fissured chalk, with flints	49.8 "
ndy clay	3.6 "	Clayey chalk	1.3 "
ay, with reddish earth	3.0 "	Soft bed	0.7 "
lastic clay	1.3 "	Very hard bed	4.6 "
oarse-grained sand	5.1 "	Hard bed	3.3 "
ifting, clayey sand	4.8 "	Hard white chalk	9.0 "
ifting, green marl sand	6.1 "	Millstone grit	2.1 "
arly sand, with broken chalk	3.0 "	Bleus (a blue impure lime-stone)	2.8 "
reen, marly sand	1.6 "	Non-aquiferous clayey marls	5 7 "
ifting, clayey chalk	3.3 "	Gray and blue chalk	124.6 "
ich chalk	6.9 "	Marl (dieve)	1.6 "
oft chalk	6.1 "	Total	265.1 ft.
ayey chalk	4.1 "		
hite chalk	2.6 "		

The natural water level was at a depth of 15 ft., and the last three rata in the list may be said to be impermeable.

Owing to the foundations around the top of the shaft, it was nec-sary to space the freezing tubes quite irregularly. Eight tubes were t down inside the shaft, on the circumference of a circle and as ar the lining of the shaft as practicable. Outside the shaft, twenty bes were spaced, as regularly as conditions would permit, over a uare of about 25 ft. on a side. The lining of the bore-holes was 14 s. in diameter at the top, 10½ ins. near the middle, and 8 ins. at the ttom. In the bore-holes, 6-in. freezing tubes, 137.8 ft. long, were aced, and the linings withdrawn. The circulating tubes were 2 ins. diameter.

Congelation was begun on April 9th, 1891, with an Osnabrück achine driven by a 40-H-P. engine, and required two hundred and ree days. Water stood to a depth of 50 ft. in the shaft during eezing. Mr. Remaux, Engineer of the work, calculated that the ngealed beds contained about 40% of water. The freezing solution as a 20% solution of calcium chloride. The temperature of the brine it left the refrigerating machine was —7° Cent. at the beginning d —16° Cent. at the end of the congelation period, and was 4° armer on its return. Just previous to starting excavation, the eight

pipes were disconnected from the freezing machine, and they were removed as the work progressed.

Freezing, however, was kept up in the outer tubes until near the completion of the work. Sinking was effected without temporary lining. Compressed powder was used for loosening the frozen material. The temperature in the shaft was about 2° Cent. when the men were working.

The lining consisted of iron rings, 4 ft. 10 ins. high, each composed of ten segments. The web was $1\frac{3}{8}$ ins. thick at the top, $1\frac{19}{32}$ ins. thick at the bottom, and was reinforced by internal ribs. The flanges were $3\frac{11}{32}$ ins. wide. The iron lining was backed by 18 ins. of concrete. To the mixing water was added 1% of caustic soda. The concrete, although frozen, was found to have set very satisfactorily. A few rings of cast-iron lining were placed below the masonry by the original method, before the work was suspended. On resuming work, the three lower rings were found to have been bent into an oval form, and they had to be removed.

No. 10, Bis Shaft, Lens Colliery.—No. 10, bis shaft is 100 ft. from the No. 10 shaft, and was sunk during 1892.

The work followed that on the No. 10 shaft, and, from the first, congelation was decided on. A pit, 20.3 ft. in diameter, was sunk to ground-water level, a depth of 11.5 ft., by ordinary means, and lined with brick masonry. From the bottom of the pit the bore-holes were started. The finished diameter of the shaft was 12 ft. The material penetrated was similar to that of Shaft No. 10. Twenty holes were put down on the circumference of a circle, 16.9 ft. in diameter, and four holes on the circumference of a circle, 7.1 ft. in diameter, to a depth of 137.8 ft. The sinking of the pit at the top occupied twenty-five days; the borings and the placing of the refrigerating tubes occupied fifty-six days. After placing the freezing tubes, the linings of the bore-holes were withdrawn. The same machine was used for congealing as at No. 10 shaft. Freezing was begun on June 8th, and was continued for seventy-five days. Near the end of the work, the refrigerating liquid had a temperature of —20° Cent. on entering the freezing pipes, and —17° Cent. on leaving them.

Excavation was begun on August 16th, and was completed on October 1st. Near the top, the excavation was made only a little larger than the finished diameter, but its size was increased toward

he bottom. Some powder was used, and the shaft was lined temporarily. The alternating bands of sand and clay proved to be somewhat nfavorable, as the clay froze much more slowly and was less hard han the other strata. Where the clay was plastic it assumed a shaly tructure, and its difference in behavior was likely to break the freezng pipes and produce cracks in the ice wall. The cracks, in this ase, however, did not result in leaks, as any water which found its vay into them was congealed before it reached the face. As soon as he excavation reached the required depth, the permanent lining was placed, working from the bottom up. The lining consisted of castron rings, 1[illegible] ins. thick, of six segments each.

No. 3, Bis Shaft, Dourges.—This shaft is located in the Department of Pas-de-Calais, France, and was sunk during 1892 and 1893.

An attempt was made to sink by pumping out, but, at a depth of 32.2 ft., the three pumps, working at their full capacity, 80 cu. ft. per econd, were still unable to control the flow. At this stage it was lecided to adopt the Poetsch system, and the excavation already nade was filled with sand.

The kinds of material to be penetrated are as follows:

Vegetable earth	1.3 ft.	Broken chalk	17.7 ft.
Clay	3.3 "	Harder chalk	8.5 "
Sandy clay	1.0 "	Chalk	12.8 "
Fine-grained limestone	1.1 "	Chalk, in thicker layers	10.2 "
Yellow sand	0.9 "	Chalk, with flints	3.5 "
Fine-grained limestone, with gravel	2.8 "	White chalk	16.4 "
Sand	1.5 "	Chalk, in thick layers	9.0 "
Sand and gravel	3.1 "	Gray chalk	14.9 "
Broken chalk	8.2 "	Chalk, with flints	7.6 "
Sandy clay, with gravel	9.5 "	Sandstone, with flints	16.6 "
Sandy earth, with much gravel	9.8 "	Sandstone, with much chalk	17.4 "
Sandy earth, slightly more compact	9.8 "	Millstone grit	11.1 "
		Total	198.0 ft.

The natural water level was at a depth of 23.3 ft. The shaft has a clear diameter of 15 ft.

The freezing fluid was circulated through twenty-four freezing tubes on the circumference of a circle 21 ft. in diameter. There was

also a tube in the center of the shaft. The freezing tubes were sunk through the millstone grit and 8 ft. into the limestone below.

Work on the borings was started on October 5th, and was completed on December 21st. After placing the freezing tubes, the lining of the bore-holes was withdrawn.

Congelation was started on January 28th, 1893, with a Fixary machine capable of producing 1 ton of ice per hour.

Sinking was begun on March 27th. The sand was found to be damp, down to a depth of 36.9 ft. Below that depth the measures were entirely frozen. Below the bottom of the previous excavation compressed powder was used. The work was carried on in four 6-hour shifts, there being six drillers and three shovelers in each shift. The rate of progress was about 5.3 ft. per day. At a depth of 105.2 ft., which was reached in May, the material was found to contain very little moisture and to be in an unfrozen condition. At the bottom of the freezing tubes the ground at the center of the shaft was found to be frozen 1.3 ft. deeper than at the sides. During the progress of the excavation the shaft was lined temporarily with oak cribbing. At a depth of 42.7 ft. excavation was suspended and a cast-iron lining placed, extending above the water level. Cement, mixed with water containing carbonate of soda, was used to back the lining.

The time required for the various operations was as follows:

Boring	76 days.
Erecting cold-producing plant	35 "
Congelation	60 "
Sinking	73 "
Placing tubing	36 "
Total	280 days.

Dourges No. 7, Shaft.—This shaft was sunk during 1894 and 1895. As this work was started after the completion of the No. 3, bis shaft, it was decided to use the freezing process from the first. The first operation was to sink, presumably to water level, a circular shaft, 27 ft. in diameter and lined with masonry.

The shaft was 15½ ft. in diameter. The materials above the millstone grit are 190.2 ft. thick. The water level was at a depth of 26.2 ft.

Twenty freezing tubes were put down on the circumference of a circle 22 ft. in diameter. A single hole was also put down in the center and insulated so as to concentrate the freezing effect at the bottom of the shaft. As at No. 3, bis shaft, the lining tubes of the bore-holes were withdrawn. The tops of the freezing tubes were at a depth of 13.1 ft.

Two Fixary machines, each capable of producing 1 000 lbs. of ice per hour, were used for congelation.

Flines-les-Raches.—This shaft is located in the Department of Le Nord, France, and was sunk mainly in 1894.

The nature of the material penetrated was as follows:

Vegetable earth	1.6 ft.	Argillaceous sand	1.6 ft.
Peat	2.0 "	Fissured chalk	11.5 "
Bluish clay	3.0 "	Compact chalk	6.6 "
Very fine-grained sand	26.0 "	Fissured white chalk	6.6 "
Gray argillaceous sand, with shells	12.5 "	Compact chalk	14.8 "
Very hard gray sand	6.2 "	White chalk	16.4 "
Plastic clay	13.1 "	Grayish chalk	6.6 "
Sandy clay	3.3 "	Chalk	62.3 "
Very dry sandy clay	10.2 "	Chalk, with flints	23.6 "
Fine-grained sandstone	2.3 "	Chalk and sand	7.9 "
		Total	238.1 ft.

The shaft is circular, and is 13 ft. 8 ins. in diameter.

Twenty-one freezing tubes were put down, to a depth of 246.1 ft., on the circumference of a circle, and a twenty-second hole was located in the center of the shaft. At a depth of 85.3 ft., a spring was encountered which gave rise to a strong flow in the bore-holes, rising 6.6 ft. above the surface of the ground. This flow was increased by another stream at a depth of 219.8 ft.

This current of water ascending along the freezing tubes would have made freezing very difficult. In order to stop it, two masonry walls were built around the top of the shaft. These walls were built to such a height as to be above the piezometric level of the water. The stream was also tapped by a bore-hole 82 ft. distant from the shaft. By these means, the level of the water was maintained at a height of 4.9 ft. above the ground. The freezing tubes were prolonged to a height of 8.5 ft. above the surface of the ground, in order to be well above the water level.

The machine used for congelation was of the Fixary type, and h a capacity of 2 200 lbs. per hour. Freezing was begun on Septemb 1st, 1894, and in thirty-eight days the ice tower was united. T freezing medium was a solution of calcium chloride.

Excavation was begun on October 25th, and carried on mainly picks and wedge needles. Near the bottom, however, compress powder was used. The central tube was dismantled as the work sinking progressed.

The lining consisted of oak cribs, about 7 ins. thick, and w placed in sections of 45.9 ft., working from the bottom of each secti upward. The timber was backed by 8 ins. of concrete. The lini was completed on May 1st, 1895.

The cost per foot was follows:

Congelation	$91.17
Sinking	8.82
Tubing	38.23
Concrete	2.94
Total	$141.16

Vicq Pits, Anzin Colliery.—This colliery is in the Department of t Pas-de-Calais, France. Most of the work was done during 1894.

The Anzin Company desired to sink two shafts through what w known to be very treacherous material, and, after considering ca fully the various methods, decided to adopt the Poetsch proce Work on the two shafts was carried on simultaneously. The t shafts are circular in plan, and 121 ft. apart, from center to cent The clear diameter of the larger, used for winding, is 16 ft. 4 ins., a the diameter of the smaller, used for pumping, is 12 ft.

A bore-hole indicated that the strata to be passed through were follows:

Vegetable earth	3.3 ft.	White marl	73.2
Greenish sand	5.6 "	Rich marl	42.9
Blackish sand	1.3 "	Marl and pyrites	4.6
Gravel	11.9 "	Sandy marl	8.5
Sand	11.5 "	Compact limestone	4.9
Sandy clay	1.6 "	Flints	41.0
White chalk	30.3 "	Impure blue limestone	36.4
Marl	31.5 "	Total	334.7
Gray marl	26.2 "		

The strata were water-bearing, down to a depth of 298.6 ft., but here existed two distinct levels: one at the surface varying with the ainfall, and capable of supplying about 6 or 7 cu. ft. per minute; the ther, in the upper and badly fissured chalk layers, was under such ressure that the water rose about $2\frac{1}{2}$ ft. above the surface as soon as n opening was made.

As a preliminary to starting work, a well, about 800 ft. distant rom the site of the pits, was sunk to the chalk, for supplying feed nd condensing water. About 3 500 galls. per hour were needed. The well was $6\frac{1}{2}$ ft. in diameter, and 49 ft. deep, and cost about $2 000. The freezing tubes were put down on the circumferences of circles the enters of which were at the centers of the respective shafts. Twenty ubes were used for the larger shaft and sixteen for the smaller one. The diameters of the respective circles were 21 ft. 3 ins. and 6 ft. 7 ins. The freezing tubes were $4\frac{19}{32}$ ins., inside diameter, $\frac{9}{32}$ in. hick, and 298.6 ft. long. The circulating tubes were $1\frac{3}{16}$ ins., inside liameter, and $\frac{5}{32}$ in. thick.

As mentioned previously, water flowed from the bore-holes (an -in. hole yielding 20 cu. ft. per minute), and in order to prevent loss f heat, it was necessary to cut off this flow. Small wells were sunk round each hole, and wrought-iron pipes, 95 ft. long, and 10 ins. in liameter, were set around each freezing tube. The tops of these ipes were above the piezometric level of the water, and the wells round the pipes were then filled with cement. The joints of the efrigerating pipes were tested to a pressure of 284 lbs. per square nch. Apparently, more than usual care was taken in making all the onnections, not only to secure tightness, but to reduce friction as vell, and to that end the collecting rings were made 8 ins. in diameter. The pits were covered with sheds with quite complete arrangements or handling the pipe and making the borings. The sheds, afterward, vere modified for use in sinking.

The problem of congelation was very carefully studied, and the alculations, in considerable detail, are given in a paper by Saclier and Waymel.* It is estimated that the measures for the first 92 ft. contained 50% of water, and that the remaining 207 ft. to be congealed contained 25 per cent. The required thickness of the ice cylinder was found to be about 1 ft. 4 ins. To produce the desired

*Bulletin de la Société de l'Industrie Minérale, 1895, p. 27.

result, it was calculated that 243 106 041 pound-calories must be removed from the ground around the larger shaft, and 191 816 799 pound-calories from around the smaller one. Allowing 25% for loss, the total to be removed was 543 653 550 pound-calories. The time allowed for congelation was one thousand hours. Accordingly, a machine capable of removing 543 700 pound-calories per hour was required. The plant installed was driven by a 200-H.-P. engine, and consisted of four Linde machines, coupled two together, and with a combined capacity of 4 tons of ice per hour. The freezing solution consisted of 30 tons of calcium chloride dissolved in 2 472 cu. ft. of water. The rate of circulation was 70.6 cu. ft. per minute.

Careful preparations were made to record the performance of the machines and to observe the progress of the freezing. To accomplish the latter, on the circumferences of circles, 27 ft. 9 ins. in diameter for the larger, and 23 ft. 3 ins. in diameter for the smaller pit, and radially opposite the freezing tubes, 2-in. pipes, 6 ft. 6 ins. long, were driven. These pipes were filled with a solution of calcium chloride, and their tops were protected from the effects of the atmosphere. Thermometers, in cases arranged so that they could be read without removing them from the solution, were lowered to the bottom.

On a line joining the centers of the two shafts, similar tubes were placed every 13 ins., thus forming a scale for noting the advance of congelation. The freezing apparatus was started on May 28th, 1894, but the four machines were not in full operation until June 12th. With all four compressors running, the temperature of the liquid on leaving the compressor was —15° Centigrade. It was from 2° to 3° higher on returning to the machine. On July 1st, the thermometers showed that the thickness of the ice on the outside of the freezing tubes was 1 ft. 5 ins., and on the inside 2 ft. 5 ins. Only two or three of the freezing machines were run after that date. On July 16th, the ice was 1 ft. 9 ins. thick on the outside and 3 ft. 3 ins. thick on the inside of the ring of pipes. On July 15th, the initial freezing operations were considered to have ended. The thermal equivalents of the work done during this period are given in Table No. 2.

It is stated that there was 20% loss in the cooling effect at the surface of the ground, owing to the distance of the machines from the shafts.

Excavation in the smaller pit was started on July 2d, and in the larger pit on July 16th. The larger shaft was excavated to a diameter

of 18 ft. 5 ins. It was lined temporarily to a depth of 100.7 ft. At that depth excavation was suspended, and the permanent lining was placed, from the bottom upward.

TABLE No. 2.

	Heat Absorbed, in Pound-Calories.	
	Smaller pit.	Larger pit.
Formation of ice	94 885 984	154 487 786
Cooling ground, outside circuits	37 093 751	62 358 974
" " inside "	31 909 341	50 524 714
Total utilized	163 889 076	267 371 474
Loss	56 381 851	72 297 511
Totals	220 270 927	339 668 985
Work of engines	221 297 078	355 723 015

Excavation at the bottom of the freezing tubes was completed on October 16th. No temporary lining was required for the second portion of the work. After lining the second section permanently, excavation, through uncongealed material, to the coal measures, was completed without incident. Below the depth of 100 ft., artificial ventilation was necessary. The temperature of the shaft lowered gradually during excavation; at first it was $+2°$ to $+3°$ Cent., at the completion of the first section $0°$, and near the bottom $-12°$ Centigrade. The workmen, however, who were employed in 8-hour shifts, suffered no inconvenience from the low temperature. During the first period the area to be excavated was only frozen slightly, and very rapid progress (6 or 7 ft. per day) was made.

The ice wall increased in thickness gradually, but a fair rate of progress was maintained to a depth of 257.5 ft., where the flints were encountered on September 15th. In this material, the thickness of the ice wall was much greater, although there was still an unfrozen core. The thickness of the ice wall varied with the material, and was much less in the fine sand than in the coarse gravel, notwithstanding the larger proportion of water in the latter. In the fissured chalk, blocks of ice, containing as much as 1 cu. yd., were encountered. The frozen conglomerate of flint was very difficult to break up. The

tools were broken and the points dulled very rapidly. As ma three thousand picks and wedges had to be sharpened in a singl In clay, sinking proceeded rapidly, and the frozen mass had th sistency of puddle cemented with ice. At the bottom of the fr tubes, 298.6 ft. below the surface, the uncongealed core still diameter of 3.3 ft. The ice was found to extend 2.8 ft. belo freezing tubes. The history of the excavation in the smaller sh similar to that of the larger, except that, owing to its smaller dia the entire mass became frozen through the flints.

At the time of the completion of the excavation to the bot the freezing tubes, observation showed that the thickness o frozen mass outside the tubes was about the same at the top an tom, and the engineers in charge state that the frozen portio roughly a cylinder. Both shafts, for a depth of 386 ft., were t with cast-iron rings, 1 in. thick at the top and $1\frac{25}{32}$ ins. thick bottom of the shaft. Concrete, 8 ins. thick, was placed behi tubbing. In the main, this was composed of two-fifths very hyd lime and three-fifths calcined coal measure shale. To the wate of calcium chloride was added.

The cost is summarized as follows:

Patent royalty, for two shafts, each 298.6 ft. deep, \$10.59 per foot	\$6 324.35
Temporary installation	3 779.33
Boring	14 218.89
Refrigerating machine, including freezing pipes, collector-rings, etc	48 009.91
Experimental apparatus	366.70
Congelation, May 28th to December 28th	6 374.98
Sinking and tubbing	55 478.82
Miscellaneous	2 448.01
Total	\$137 000 99

The cost is given by Messrs. Saclier and Waymel as \$177.46 p of shaft. This, evidently, is for the 386 ft. of tubbed shaft, of a depth of 298.6 ft. was in congealed material.

In the paper by Messrs. Saclier and Waymel, the engineer eral interesting conclusions are given, and these may be summ as follows:

The bore-holes must be absolutely plumb. For depths not ex-ding 328 ft., they may be spaced 4 ft. apart. For depths of 656 ft., y should not be more than 3.3 ft. apart. The radial distance of the es from the center of the shaft should not exceed the radius of the ft by more than 2 ft. Freezing tubes should not be placed inside shaft, for two reasons:

1.—Excavation is much more difficult when the entire mass is zen.

2.—Bodies of water are likely to be imprisoned between the inner ss and the annular ice wall. The advance of congelation will then duce pressures which may rupture the ice walls. The refrigerating es should be tested carefully, and should be of a metal as soft as cticable. The collecting rings should be of large cross-section, l all connections with circulating pipes should be made in uniform nner.

No. 9, Shaft, Courrieres Colliery.—This colliery is in the Department Pas-de-Calais, France.

The sinking was practically accomplished in 1894. An attempt was de to sink this shaft by pumping. At a depth of 102.5 ft., three mps, lifting 8.5 cu. ft. per second, could not handle the water. As re was no room for additional pumps, this method was abandoned, l the Poetsch system adopted.

The material penetrated was as follows:

getable earth	0.7 ft.
llowish clay, mixed with chalk	9.2 "
ne potter's clay	1.6 "
nd, mixed with potter's clay and marl	11.5 "
ne marl	3.3 "
ne marl, with flints	78.6 "
Gray marl	23.3 ft.
Gray marl, with flints	6.9 "
Gray-yellowish marl	4.9 "
White marl	9.8 "
Gray and stronger marl	2.1 "
Millstone grit	12.6 "
Impure blue limestone	1.0 "
Total	165.5 ft.

The last two strata were impermeable.

The shaft was circular in plan and 15 ft. in diameter. Twenty-ır pipes were put down on the circumference of a circle 22 ft. in meter. A twenty-fifth pipe was sunk in the center and insulated as to freeze only the material near the bottom. The refrigerating pes were 171.5 ft. long, and their internal diameter was $4\frac{17}{32}$ ins. The ameter of the circulating pipes was $1\frac{5}{16}$ ins.

The freezing plant consisted of two Fixary machines, of 1 100 lbs. capacity per hour. The freezing solution was calcium chloride.

Congelation was started on April 7th. Excavation was commenced on June 25th, and was completed on July 17th.

The lining was of timber backed by concrete. The water used for mixing the concrete contained a solution of carbonate of soda to prevent freezing.

To complete the work, two hundred and twelve days were required, distributed as follows:

Boring wells and lowering brine pipes.........	102	days.
Erecting refrigerating plant....................	10	"
Freezing..	78	"
Sinking, excavation..........................	22	"

Venus Tiefbau Colliery (Winding Shaft).—This shaft is at Brux, Bohemia. The construction required from January, 1895, to June 1st, 1896.

The coal beds of this part of Bohemia are covered by a thick bed of quicksand, and several attempts to penetrate it at different points have met with failure. One instance is cited where the quicksand broke into and nearly filled a mine. The owners of the Venus Tiefbau Colliery first attempted to sink by ordinary means, and to line the shaft with masonry. As the quicksand was approached, it burst into the shaft and filled it to a height of 72.2 ft. A depth of 19.7 ft. was gained, after pumping out, but a second rush stopped work by this method. Next, an attempt was made to sink a masonry lining built on piles by excavating from the bottom. After advancing about 26.2 ft., there occurred a third break of such violence as to throw the masonry out of plumb, and put a stop to work by this plan. At that stage the Poetsch process was adopted.

The nature of the material encountered was as follows:

Clay..................	105.0 ft.	Quicksand	23.0 ft.
Quicksand.............	72.2 "	Clay..................	196.8 "
Clay	59.1 "	Total.............	456.1 ft.

The pressure in the upper layer of quicksand was two atmospheres, and in the lower layer, from seven to eight atmospheres.

The clear diameter of the shaft was 13 ft. 5 ins. Twenty-four holes were put down on the circumference of a circle having a diameter

f 26 ft. 2 ins. The freezing tubes were placed inside the lining of ne bore-holes. Instead of having their lower ends welded, the freezig tubes were closed at the bottom with a screw-plug which could be emoved from the top. This provision was made in order to allow the scape of the freezing liquid upon the completion of the work. It was hought that the brine would help to thaw the pipes free and aid in heir withdrawal.

The borings were started in the middle of January and completed bout April 15th.

The refrigerating apparatus was of the Carré-Kropff type, and onsisted of three machines. One had a capacity of 1 ton of ice per our, and each of the others a capacity of half a ton. Seldom more han two of the machines were used at a time. Congelation required rom June 1st to December 2d, 1895.

Sinking was commenced on December 2d, and progressed at the ate of about 3.3 ft. per day. At a depth of 108.3 ft., some water ntered the shaft, and sinking was interrupted until these openings vere completely frozen. Below a depth of 173.9 ft., the entire central nass was congealed. The frozen quicksand had the compactness of oft sandstone, and was excavated with picks and wedges. Only a ight temporary lining was required.

After passing the lower quicksand bed, on February 10th, 1896, he permanent lining was begun. Except through the quicksand, the ning was of masonry. In the lower strata, iron tubbing was used, nd in the upper strata dove-tailed concrete blocks. On May 15th, 896, the lining was completed and the freezing machine stopped. The shaft was filled with water at a temperature of 50° to 60° Cent. to ssist the setting of the mortar and to thaw the ice wall. On pumping ut the shaft, it was found to be practically tight.

Prof. Petrilk gives the total cost of lining and sinking at about $140 per foot.

It is stated that the air-shaft, also, was sunk by congelation. This shaft was about 130 ft. from the winding shaft.

Ligney-Les-Aire Shaft.—This shaft is in the Department of Pas-de-Calais, France. The work was done during 1895 and 1896.

The thickness of the permeable covering to be penetrated was bout 270 ft. The borings and the installation of the freezing machinery occupied the time from the end of April to October 12th, 1895. Congelation was started on December 19th, producing a temperature

of —5° Centigrade. The temperature of the ground at this time +12°.

Sinking was begun on February 19th, 1896, and on May 6t end of the frozen ground was reached, at a depth of 300 ft.

The lining was cast-iron tubbing, in rings 5 ft. high, consisti eight segments. The tubbing was founded on a timber crib a bottom of the shaft. The lining was completed on July 16th, 18

Auboué Iron Mine.—This mine is in the Department of Meurt Moselle, France. Operations were begun in 1898, and the shaf completed in 1900.

The construction of other shafts in the vicinity, by diff methods involving pumping, proved to be very slow and co Accordingly, it was decided to adopt the Poetsch process.

The finished diameter of the shaft is 16.4 ft., but, to allo placing the lining, it was excavated to a diameter of 18.5 ft.

The material penetrated was as follows:

Soft, shelly yellow limestone	31.2 ft.
Alternating soft yellow limestone and sandy marl	4 9 "
Compact limestone, alternating with chalk	29.5 "
Very hard gray limestone,	44.3 "
Very hard white granular limestone	14.7 "
Broken crystalline limestone, intercollated in rare places with chalk	32.9 "
Soft yellow limestone, alternating with crystalline limestone and hard sand	42.7 "
Crystalline limestone	9
Crystalline limestone	16
Soft yellow limestone	14.
Gray limestone	6.
Ferruginous limestone	6.
Hard limestone and marl.	11.
Ferruginous limestone	9.
Gray marl	9.
Ferruginous limestone	3.
Ferruginous marl	9.
Pure gray micaceous marl	39.
Total	338.

As a preliminary to making the borings, a well, 24 ft. in diam was sunk to ground-water level, a depth of about 20 ft., and lined masonry. It was first planned to use twenty freezing pipes, loc on the circumference of a circle 21.4 ft. in diameter. Many of

From *Le Genie Civil*, 1901-1202
To Accompany Description of Auboué Shaft.

Direct

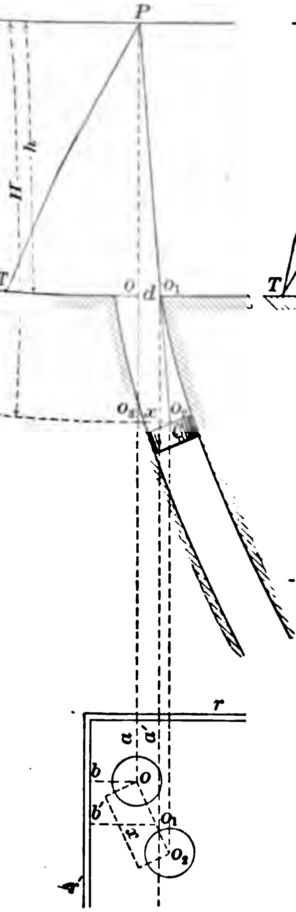


FIG. 35

Indirect

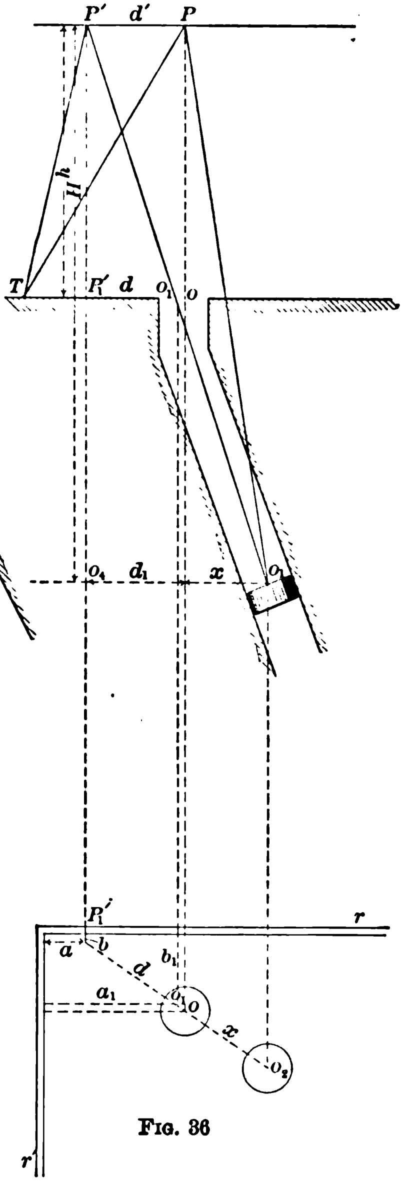


FIG. 36

bore-holes, however, deviated from the perpendicular, and it was necessary to reject those which approached the center of the shaft. Those which diverged from the center of the shaft, or from each other, were accepted, provided the deviation was not too great. In all, thirty-one holes were bored, of which twenty-four were used for congelation. The diameter of the first borings was 8 ins., and of the later ones 12 ins. The distance of the latter from the center of the shaft was also increased to 11.5 ft. The 12-in. holes were found to be much more nearly vertical than the 8-in. holes. The freezing and circulating pipes were 4.8 ins. and 1.3 ins. in outside diameter, and 0.2 and 0.117 in. in thickness, respectively. The depth of the holes was 459.3 ft. The tops of the freezing pipes were just above the bottom of the well. One hole was bored in the center to relieve any pressure which might be occasioned by variable rates of freezing in the different strata.

Congelation began on March 29th, 1899, with two Fixary machines, each having a capacity of 2 200 lbs. of ice per hour. Each machine was driven by an 80-H-P. engine. In general, the temperature of the descending brine was —17° Cent., and of the ascending —12° or —13° Centigrade. Congelation required one hundred days, and, after excavation was started, on July 6th, only one machine was operated. To facilitate excavation, a hoisting house was built over the shaft, and an annular lining was placed in the well to shut off the tops of the freezing pipes from the main portion of the shaft. Black powder was used at first, but, later, dynamite was adopted with much better results. At the minimum temperature, the pipes contracted 2.4 ins., and those which were gripped so tightly by the surrounding material that they could not move were ruptured at the joints. When a leak occurred opposite the unlined portion of the excavation, the pipe was uncovered by means of a small tunnel, and a water-tight gasket or collar was placed around the break. When the breaks could not be reached in this way, a third pipe, 2.75 ins. in diameter, was placed in the hole, and served as the freezing tube. The rate of progress of the excavation varied from 10 ins. per 24 hours in hard rock to 6½ ft. in micaceous clay.

Three shifts were employed, each consisting of one foreman, seven miners and seven helpers. The average rate of excavation, for actual working time, was 23 ins. in a 24-hour day. Very little temporary lining was required. The shaft below the well was dug in six sections,

of which the upper five, aggregating 368 ft., and passing wholly through water-bearing strata, were lined with cast iron backed by concrete. The sixth section was lined with masonry. In order to shut off percolation, at depths of 338 and 394 ft. below the surface, masonry rings enclosing the freezing tubes were built around the shaft. When the freezing pipes were uncovered to place the lower ring it was found that one of them, 18-*a*, was not coated by frost. This indicated that circulation in that pipe had stopped. At about the same time one of the adjacent tubes was pierced by a drill and had to be disconnected temporarily. Difficulty in locating two of the freezing tubes caused a delay of a week in completing the masonry ring. At the end of that time, water burst into the shaft, near the tube 18-*a*, flowing at the rate of about 6 cu. ft. per minute. For several hours, efforts were made to close the break, but the flow increased gradually and compelled the workmen to abandon the shaft. In order to prevent the wearing away of the ice wall by this flow, water was pumped in from the outside until all flow through the break was stopped. To hasten congelation, the second freezing machine was started, but, a break occurring in one of the pipes, all the brine was lost and congelation had to be suspended. Before the leak could be located, it was necessary to remove all the inner tubes. These were second-hand, and had been corroded badly by long exposure to the brine. Some of them were broken, and much time was lost in recovering the lower portions. The scale or rust from the pipes had fallen to the bottom of the freezing tubes, filling them in some cases to a depth of from 3 to 6 ft. It became necessary to shorten the inner tubes by corresponding amounts before they could be replaced. Altogether, fifty-three days were lost on account of the break in the ice wall.

The sinking and lining were completed on July 5th, 1900.

Harchies Shaft, Blaton Colliery.—This shaft is in Harchies, Belgium. The sinking was accomplished during the years 1899 and 1900.

The shaft is 787 ft. deep, and, on account of the nature of the material encountered, Mr. Saclier, who prepared plans for the work, considered some special precautions necessary. The trial boring, Fig. 14, showed that, between the depths of 76.6 ft. and 168.0 ft. below the surface, there existed a bed of impermeable clay, and, directly beneath this, 575.8 ft. of water-bearing material, mostly greensand. The specific heat of the clay was said to be not more than 0.2, while

that of the greensand, owing to the large quantity of water it carried, was thought to be much higher. Under these conditions, it was probable that the clay within the ring of the freezing tubes would be frozen to the center, while beneath there would exist a cylinder of uncongealed sand and water surrounded by an annular ring or wall of frozen material. The further thickening of the ice wall toward the center would give rise to pressure in the central cylinder, which would no longer be relieved by the escape of the water upward through the clay. It is conceivable that this pressure might become great enough to flatten or crack the freezing tubes, or even rupture the ice wall itself. In order to guard against this contingency, a central tube was put down to the bottom of the greensand to form a means of escape for the water under pressure by rising and flowing off at the surface. To prevent the tube from being closed by freezing through the clay, a steam pipe was provided whereby it could be warmed down to the bottom of the clay. It was also thought that by observing the pressure of the water in the tube a fair idea could be obtained of the progress of congelation. Although the shaft has been completed, information is not at hand to show whether these theoretical conditions existed in actual practice.

The bore-hole previously mentioned penetrated the following formations:

Vegetable earth.......	1.6 ft.	Greensand............	246.9 ft.
Chalk.................	26.6 "	Clayey greensand.....	60.7 "
Glauconiferous marl...	4.8 "	Greensand............	206.0 "
Chalk.................	14.3 "	Clayey greensand......	33.0 "
Blue impure limestone.	29.2 "	Soft yellowish sand....	23.4 "
Impermeable clay......	91.4 "	Coal measures.........	328.1 "
Tourtia................	5.7 "	Total.............	1 071.7 ft.

The strata below the impermeable clay and above the coal measures contained water under sufficient pressure to produce a flowing well with a head of 16.4 ft.

Fig. 14 shows the freezing pipes surrounding the shaft.

The freezing machine was rented from the Anzin Company, and was the same as that used for sinking the Vicq pits.

Congelation was commenced on May 16th, and sinking on August 1st, 1899. Several of the freezing tubes were ruptured, and, instead

SECTION OF RECENT FORMATION PASSED THROUGH FOR AIR SHAFT FOR MINE MARIA

From *Gluckauf*, 1901.

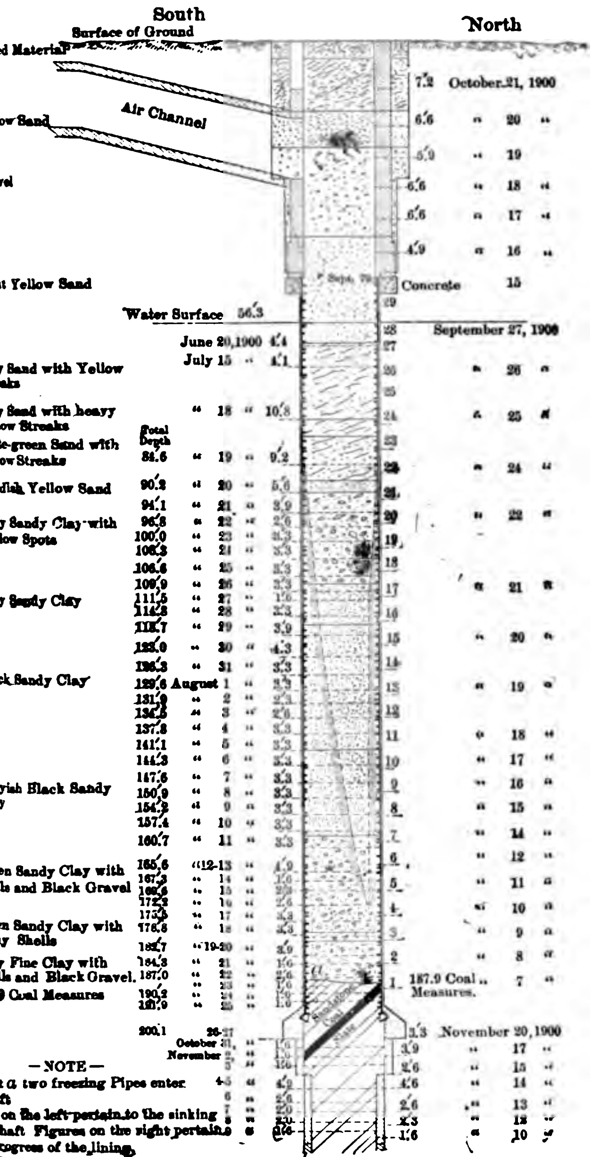


FIG. 37.

of trying to repair them, the inner tube was withdrawn and repl by two small pipes connected at the bottom. This arrange worked very satisfactorily.

The excavation was completed on October 24th, 1900. V freezing was discontinued, the inner tubes were withdrawn and freezing tubes were filled with concrete.

The lining was placed in sections of 164 ft. each. At the botto each section was formed a ledge supporting cribs, from which lining was started. The latter was in rings, 4 ft. 10 ins. high, ca four segments. While the lining was being placed, excavation in progress in the next section below.

The Poetsch process was adopted for sinking Shaft No. 2, in same locality.

Maria Shaft.—This shaft belongs to the Maria Mine, near Aac Germany, and was sunk during 1899 and 1900.

It was designed for both hoisting and ventilation, and replace old ventilating shaft. Its total depth is about 270 ft. The mat was water-bearing to a depth of about 188 ft. Congelation adopted for this portion of the work. The contract was give Gebhardt and Koenig, of Nordhausen. The contractors ag barring certain unavoidable accidents, to complete the 188 f fifteen months, from July 1st, 1899. The proprietors of the guaranteed that no warm springs or salt-water deposits would b countered. The contractors were to maintain the ice wall unti lining was placed and a safe connection made with the material.

The shaft was circular in plan, and 13.1 ft. in diameter.

The material in the first 188 ft. was clay, gravel, sand, sandy cla firm clay. The order of their occurrence is shown in Fig. 37. water level was 56.3 ft. below the surface.

The borings for the freezing tubes were started from the bott a well 27.5 ft. deep. There were twenty-four freezing tubes, sp equidistant on the periphery of a circle 24.6 ft. in diameter. bore-holes were 7¾ ins. in diameter at the surface, and, approxima 6 ins. at the bottom. They were 190.2 ft. deep. The inside dia of the freezing tubes was 3¾ ins. The inside diameter of the circ ing tubes was 1 in., and the metal was ¼ in. thick. The fre tubes were provided with elastic joints, in order to permit

contraction under low temperatures. The casings of the bore-holes were withdrawn after the freezing tubes were placed. The collecting and circulating rings were placed at the bottom of the well.

The freezing apparatus was driven by a 120-H.-P. engine. The freezing medium was chloride of magnesium. The freezing machine was started on March 23d, 1900, but, owing to delays for some improvements made in the apparatus, it did not work regularly until May 25th.

During the delay, the shaft was excavated down to ground-water level and lined with U-rings of fluted tubbing. On June 20th, 1900, the excavation was carried to a depth of 4.4 ft. below water level. The material was yellow sand, and water entered from the sides, exposing some of the freezing tubes.

Excavation was discontinued, and the shaft was refilled with sand and clay. On July 16th, excavation was resumed, although the unfrozen core was still 14 ft. in diameter. The size of the core decreased gradually, and, at a depth of 33 ft., it became necessary to point the walls of the shaft. Later, resort was had to blasting with compressed powder. The holes were about 4 ft. deep, and inclined at an angle of 75° toward the center of the shaft. The charges used consisted of from 7 to 10 oz. of powder. In sinking the shaft, there were three 8-hour shifts of eight men each per day. The 131 ft. below ground-water were excavated in forty days. It was feared that the low temperature would have an injurious effect on masonry. Iron tubbing was adopted for the lining.

As shown in Fig. 37, the soft core was found to be located quite eccentrically to the center of the shaft. Two of the bore-holes had deviated so far from the perpendicular that they were encountered by the excavators. The tubes were thrown out of commission, temporarily, and those portions within the shaft were cut off. The end was then closed and the use of the shortened tubes resumed.

A leak occurred in the ice wall a short distance below water level, but the water was collected in a pipe and hoisted to the surface.

Ronnenburg Alkali Works.—These works are near Hannover, in Germany. Work was begun in 1898 and completed in 1901.

The first plan adopted was to sink by ordinary methods for 131 ft., and then, with hydraulic pumps, force down a cast-iron shell pro-

vided with a cutting edge. The inside diameter of the first section was 21.3 ft. It was lined with masonry 2.6 ft. thick. Below a depth of 23 ft. the quantity of water pumped was 24 cu. ft. per second, and, below a depth of 88.6 ft., the character of the material proved to be very bad. At a depth of 105 ft. the masonry walls were displaced laterally 4 ins. In spite of all effort, the pit soon filled with water up to a depth of 25 ft. After experiments had shown that the ground-water, which contained about 3% of salt, could be frozen, the Poetsch process was adopted. Tests were made with brine solutions containing, respectively, 4, 8, 10, and 12% of chloride of sodium. These solutions were placed in the ice machine and submitted to a temperature of —12° Cent. for 48 hours. The shaded areas, in Fig. 38, show the ice formed in that time. The proportions of salt in the ice and in the uncongealed liquid are also given for each case.

The finished diameter of the shaft was 19.7 ft.

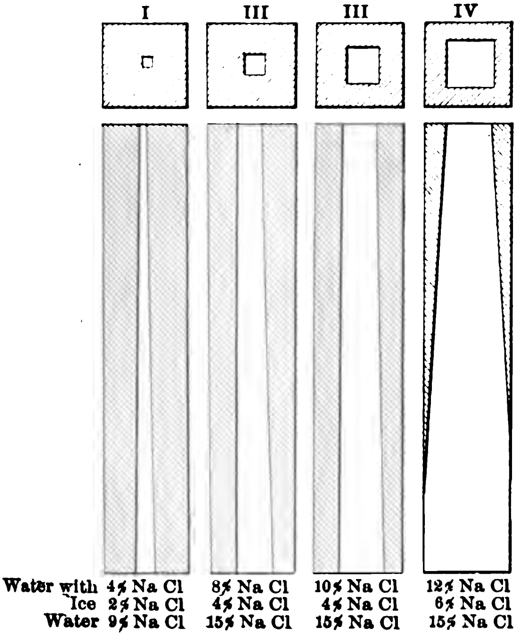
The material penetrated was as follows:

Soil	1.6 ft.	Firmly compact gypsum	128.8 ft.
Yellow sandy clay	14.8 "	Very firmly compact gypsum	18.0 "
Sand and clay	10.7 "	Gypsum, with clay	59.7 "
Sand	2.3 "	Gypsum, with gray and green clay	4.8 "
Blue and yellow clay	4.7 "	Green clay, with grains of quartz and apatite	41.0 "
Blue clay	51.2 "	Firmly compact gypsum.	17.5 "
Gypsum	30.7 "	Gypsum, with clay	0.5 "
Fissured gypsum	24.6 "	Firmly compact gypsum.	32.8 "
Gypsum	2.8 "	Total	459.3 ft.
Sand	2.6 "		
Gypsum	5.9 "		
Fissured gypsum	4.3 "		

The freezing tubes were put down on the periphery of a circle having a diameter of 29½ ft. Considerable trouble was caused by the deviation of the holes from the vertical. In all, thirty-five holes were bored, but probably only thirty were used for congelation. The freezing tubes were 413 ft. long. One hole was bored in the center of the shaft to a depth of 2 953 ft., but, afterward, it was plugged at a depth of 577.5 ft. The diameter of the freezing pipes was 5 ins. and the thickness of the metal ¼ in. Common gas pipe, 1½ ins. in diameter, was used for the circulating pipes. The circulating and collector

From *Gluckauf*, 1901

To Accompany Description of Ronnenberg Mine



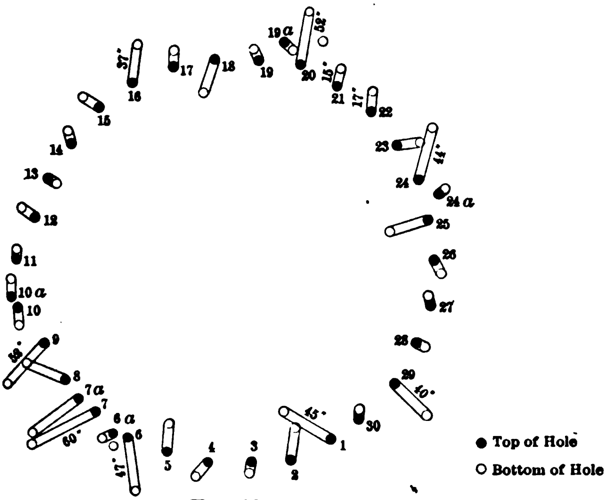


FIG. 38

rings were of cast-iron pipe, 11 ins. in diameter. The pipes a ground were painted with a coating of tar and cork and covered cork and ashes. The rings were placed at a depth of about 6 ft. b the surface, to avoid the effects of surface temperature as far as sible.

In the design of the freezing apparatus, its capacity was dou on account of the salt in the ground-water. The calculated capa was 240 000 frigories per hour at —25°, or 300 000 at —15° Centigr A test, however, showed the actual output to be 383 000 frigori —15° Centigrade.

The refrigerator was of the Fixary type, and was driven by engines developing 70 or 80 H.-P. A 28% solution of calcium chlo was used in freezing.

Congelation was started on January 19th, and excavation a May 1st, 1901. At that time the temperature of the solution, o turning to the machine, was about the same as when it entered pipes, *i.e.*, —20° Centigrade. On July 15th, a depth of 226 ft. had reached without incident. Blasting was permitted only in the ce of the shaft, and excavation was carried on mainly with picks shovels.

Pit No. 2, Ligney-Les-Aire.—This shaft is near Estrée-Blanch Northern France, and was sunk in 1900–1901.

The material penetrated was as follows:

Vegetable earth	7.4 ft.	Yellowish marly chalk ..	74.
White marly chalk	59.1 "	Bluish clayey chalk.....	154.
		Total..............	295.

The water level was at a depth of 114.8 ft., and there was a g deal of water to contend with.

The finished diameter of the shaft was 13.1 ft. Before starting borings, a pit, 23 ft. in diameter, was sunk to a depth of 9.8 Eighteen holes were then put down from the bottom, on the circ ference of a circle having a diameter of 19.7 ft. The depth of the h was 305.1 ft. The borings were commenced on May 1st and compl on September 29th, 1900.

A Fixary machine, having a capacity of 2 200 lbs. per hour, used for congelation.

The period of excavation and freezing extended from Novem

, 1900, to June 24th, 1901. The total time required was two hun-
ed and twenty-seven days.

Washington Colliery.—This colliery is near Washington, in County
rham, England.

The first or larger shaft to which this description is mainly devoted
s sunk in 1902.

Some old abandoned openings existed on the property, but the
ners decided to install a modern system of working, and discarded
old pits. The adopted plan called for two circular shafts, 14 ft.
d 12 ft. in diameter, respectively. As there had been much trouble
sinking by ordinary means, in the same locality, the Poetsch pro-
ss was adopted from the first. Considerable interest is attached to
is sinking, as it is said by Mr. Mark Ford, the manager, to be the
st application of the process in England. The contract for both
afts was given to Messrs. Gebhardt and Koenig, of Nordhausen,
rmany. The installation of much of the plant was made with regard
the sinking of the smaller shaft, but, from the information at hand,
does not appear that actual operation were begun on the smaller
til after completion of the larger pit.

The material penetrated was as follows:

il	1.3 ft.	Clay, with boulders, dry	12.9 ft.
llow sand, dry	34.5 "	Loamy clay, dry	5.2 "
ay sand, wet	41.3 "	Stiff clay, with boulders, dry	9.6 "
ue clay	0.1 "	Yellow freestone	13.0 "
ay sand, with a gravel bed, damp	2.3 "	Total	120.2 ft.

The wet sand contained about 19.6% of water.

As a preliminary to sinking the tubes, a well, 24 ft. in diameter,
s sunk to a depth of 24 ft. This well was lined with plank supported
wooden cribs, 6 ins. square and spaced 3 ft. apart. Twenty-two
re-holes were spaced equidistant around a circle having a radius of
.25 ft.

The borings penetrated the freestone 1 ft. 6 ins. The holes were
ns. in diameter, and considerable trouble was experienced in keep-
g them vertical, especially through the boulder clay. Four-in.
eezing tubes with outside sleeve joints were inserted in the holes,
d the casings withdrawn. Six sets of casings served for twenty-

two holes. The circulating tubes were 1 in. in diameter. The circulating and collector rings were about 8 ft. above the bottom of the well. In the middle of the shaft was placed a tube, 18 ft. deep, from which the temperature and height of the water were noted, "as the gradual increase of the ice wall slowly caused the water to rise." Before starting congelation, the top of the shaft was enclosed and the exposed pipes were covered with straw rope.

The freezing plant was of the ordinary ammonia type, and was in duplicate. The engines were of 55 H.-P. The circulating medium was a solution of chloride of magnesium containing about 26% of salt. This solution freezes at a temperature of $-34°$ Centigrade. The temperature of the solution on leaving and returning to the refrigerator is shown clearly in Fig. 10. The brine was circulated at the rate of 144 galls. per minute. The initial freezing period covered forty-three days.

On May 5th, 1902, at the end of the forty-three days, excavation was commenced. The sinking was made 17.8 ft. in diameter to allow for lining. Through the sand, a core, 6 ft. in diameter, was always soft, and the remainder could be worked readily with a pick. In eleven days 55 ft. were excavated. In the clay, however, the ice wall was much thicker. The central core was partially frozen, and never more than 2 ft. in diameter. Recourse was had to blasting, but, owing to the brittle condition of the tubes, great care had to be exercised. Gelignite was used as the explosive, and the charges consisted of ¼ lb. to a hole. Brine had to be used instead of water in drilling, as the latter froze so quickly that it held the drills in the holes. One of the freezing tubes was split, probably owing to the effects of a shock, and had to be thrown out of use. In the sand, the shaft was sheathed temporarily with wooden cribs, 6 ins. square, and lagged with planks. For a short distance in the wet sand, iron was used, instead of wood. As soon as the freestone was reached, a cast-iron segmental ring was placed, and from this the permanent lining of brickwork was started.

In general, the lining consisted of two concentric rings of brickwork, each 9 ins. thick, with a 2-in. annular space between them. This space was filled with cement. The brickwork was laid in cement mortar. To prevent the mortar from freezing, it was mixed with water containing 7% of caustic soda. After the completion of the

ning, the freezing tubes were removed and the holes filled with ment mortar. The removal of the tubes was facilitated by the cir- ilation of steam, but, in some cases, the lower sections were lost.

There was some difference of opinion as to the necessity of freezing e boulder clay, but the contractors refused to take any responsi- lity as to the sinking of the second pit if it were not done.

Shaft No. 1, Laura and Vereeniging Colliery.—This colliery is in the rovince of Limburg, Holland.

The date of the work is not given, but was probably some time uring the years 1900 to 1902, inclusive.

As about 270 ft. of watery sand were to be penetrated before the al measures were reached, the Gebhardt and Koenig process was lopted. This, apparently, is the Poetsch process improved and odified in some of its details.

The shaft is 14.8 ft. in clear diameter.

The material penetrated was as follows:

oam	26.6 ft.	Greensand	4.9 ft.
ravel	4.6 "	Clay, mixed with shells	8.2 "
reensand	14.4 "	Sandy clay	13.1 "
ellow sand	13.1 "	Greensand	36.1 "
reensand	81.3 "	Gray sand, with brown streaks	13.1 "
reen clay	45.9 "	Greensand	48.5 "
reensand	6.6 "		
reen clay	6.6 "	Total	323.0 ft.

The water level was at a depth of 27.9 ft. The 295.1 ft. between e water level and the coal measures were all heavily water-bearing. he coal measures, themselves, to a depth of 333.0 ft. below the sur- ce, were fissured, and, consequently, contained considerable water. elow this there was a layer of compact sandstone, then compact, aty ground. Previous to sinking the freezing tubes, a well, about) ft. in diameter and 28 ft. deep, was sunk and lined with rings of iannel irons supporting planking.

From the bottom of this well, twenty-four freezing pipes were put own on a circle having a diameter of 23.9 ft. The freezing tubes ere 4 ins. in diameter, and were provided, at about mid-depth, with lastic unions to prevent breakage by contraction. The depth to which ie tubes were placed is not stated, but, probably, they did not pene-

trate very deeply into the coal measures. They were tested carefully as to their verticality, and, later, were found to be practically true. The circulating tubes were 1¼ ins. in diameter. The distance between the borings was about 2.9 ft.

The cold-producing apparatus was of the carbonic-acid type, and a double compressor was used. The refrigerating liquid was a 30% solution of chloride of magnesium, and left the cooling tanks at a temperature of —20° Centigrade. In eight days after the freezing machine was started, the wall of ice around each of the pipes was 20 ins. thick. During the early portion of the freezing period, there were several interruptions.

Sinking was begun three months after congelation was started. For the entire distance down to the coal measures there was an unfrozen central core. Excavation was carried on with hammers and chisels. No powder was used, as there was some fear of injuring the ice walls. There were occasional soft spots, due to the escape of the freezing solution, but these did not cause any trouble. The rate of progress was about 4.9 ft. per day, and the coal measures were reached without incident. However, on attempting to widen the shaft, in the coal measures, a collapse occurred on the south side of the shaft. The pit was partially filled with water, and sand rose to a height of 131 ft. In order to prevent further damage to the ice wall, the shaft was filled with water up to its natural level. To strengthen the ice wall, six tubes were put down on the south side of the shaft and on the periphery of a circle 36 ft. in diameter. Twelve tubes were also sunk inside the shaft as near as possible to the walls. All these tubes extended 33 ft. into the coal measures. In boring the outer holes, no cavities were discovered behind the ice wall, but the ground, evidently, had been greatly disturbed. During this operation, two subsidences of the earth occurred on the south side of the shaft. The sinking of the holes inside the shaft was accomplished with considerable difficulty, particularly as the workmen, on abandoning the shaft, had left all their tools behind. After freezing had advanced sufficiently in the new tubes, the work of excavating the sand was started, and, at a depth of 230 ft., the mass was found to be entirely frozen.

The provisional timbering was uninjured, and the channel rings were in their original position. This indicated that the ice wall had

From *The Iron and Coal Trades Review*, Vol. LXVI.
To accompany Description of Laura and Vereeniging Shaft.

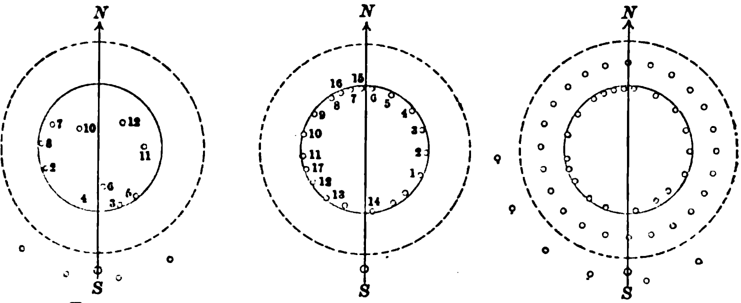


FIG. 39. FIG. 40 FIG. 41

DIAGRAMS SHOWING LOCATIONS OF BORE-HOLES.

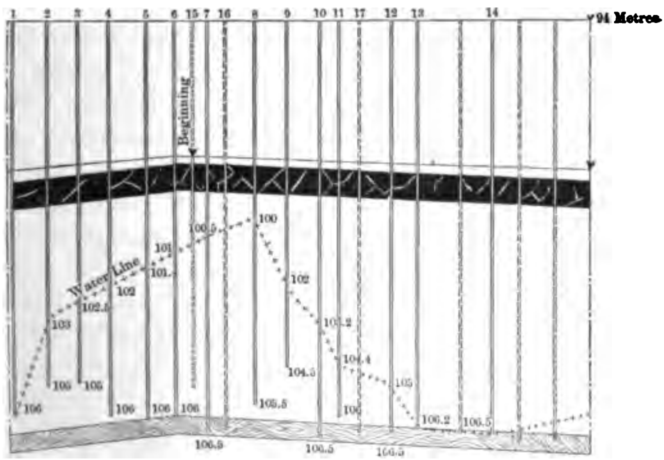


DIAGRAM SHOWING DEVELOPMENT OF BORE-HOLES MARKED IN FIG. 40.
The beginning of the Coal Measures at a depth of 98½ metres is shown by the black arrow head.

FIG. 42

remained undisturbed. It was soon found that the tubes inside the shaft, particularly those on the north side, had deviated very considerably from the perpendicular. The position of all the holes of the second set, at the level of 278.9 ft. below the ground, is shown in Fig. 39. At the depth of 308 ft. the deviations had increased considerably, and it was not deemed safe to proceed further with the excavation until additional tubes were placed. The bent tubes were removed, and a third series, of fourteen holes, was started on the level of 308 ft. below the surface of the ground, and located as shown in Fig. 40. In order to avoid interfering with the wedging cribs, used for supporting the permanent lining, these new holes were started on an inclination of 5% outward from the vertical. To guard against a sudden inrush of water, the boring rods were worked through stuffing boxes in hollow guides set in concrete at the bottom of the shaft. The cold was severe, the temperature being at times as low as —13° Centigrade. The water for washing out the borings froze quickly even when warmed, and it was found necessary to use a weak solution of chloride of magnesium.

In making these borings, the limit of congelation, indicated by the presence of water, was noted, and is shown graphically on the developed surface, Fig. 42. The freezing tubes had to be inserted quickly in order to let as little water as possible into the shaft. Tube No. 11 gave considerable trouble, as a spring of water broke out along the outside and could not be stopped even after freezing was started. After a number of expedients had failed, it was finally choked, at the end of about four weeks' time. This third series was connected to circulating and collector rings placed about 20 ft. above the bottom of the shaft. After congelation had been completed, Holes Nos. 15, 16, and 17, Fig. 42, were driven to a depth of 349 ft., and showed that the ground was completely frozen. The freezing tubes which were working at this stage are shown in Fig. 41. Forty freezing tubes were now in operation, and it was feared that, through the intense cold, the expansion of the material might fracture the frost wall, and for this reason some of the pipes were put out of use occasionally.

Soon after the resumption of the excavation, it was found that the tubes of the third series were all nearly vertical and did not leave room for placing the ordinary wedge cribs for supporting the lining. At a

epth of 336 ft., excavation was suspended. Two fluted tubbing rings vere designed, to take the place of the wedge cribs, and served the urpose admirably. These rings were composed of segments, 60 ins. igh, and had two horizontal ribs as well as flanges for the full length f the segment. Between these ribs the web was arched outward. 'hese rings did not differ from the ordinary rings used for the entire haft, except in the arched webs. The two rings were placed care-illy at the bottom of the excavation, and the space between them and ie ice walls was filled with a quick-setting concrete. To render the oncrete frost-proof, a 20% solution of calcidum was added, and roved very satisfactory. Previous experiments proved that a solution f soda failed in its effect, and that a solution of magnesium chloride iminished the solidity of the concrete. After the tubbing was ompleted to the surface, excavation was resumed.

The time required for completing the shaft to the coal measures was venty and one-half months, divided as follows:

Making borings and fitting up tubes........	3	months.
Mounting ice machine, etc..................	2	"
Congelation..........	3	"
Sinking, before accident..................	3	"
Placing additional tubes and congelation...	8½	"
Excavation, etc............................	1	"
Total..............................	20½	months.

Work is now in progress on a second shaft, and, profiting by xperience, the tubes will be sunk about 15 ft. into the coal measures.

Other Projects.

Under this heading are included the projects for and actual applica-on of the freezing process of which only brief mention has been ound. Such information as is available is given in each case.

Bucharest, Roumania.—*Engineering News*, of July 5th, 1884, states iat Mr. Poetsch has just closed a contract to sink a series of bridge iers at the above locality. The writer has been unable to find any irther details in regard to this matter, and is uncertain whether or ot the contract was ever carried out.

Wyoming, Pennsylvania.—Mr. Edward L. Abbott, and a number of ie technical journals, refer to the fact that freezing pipes were being

placed for sinking a shaft in the Wyoming Valley, Pennsylvania. No further published information could be found, but inquiry of Mr. R. V. Morris, Chief Engineer of the Coal Companies, Wilkesbarre, Pennsylvania, elicited the following information:

"I find on investigation that the freezing process has never been actually used in shaft sinking in this region, though it has been attempted in one case of which the following is the history given by Mr. J. U. Crawford, now of the Peoples Coal Company, Scranton, Pa.

"In 1889 the Mt. Lookout Coal Company, of which Mr. Crawford was then Superintendent, started to sink two shafts near Wyoming, the strata, as developed by test holes, showing approximately 32 ft. of dry gravel, and 70 ft. quicksand above the rock. The first shaft was sunk by pneumatic process with a square caisson, and, while it was in process of sinking, an attempt was made to sink a second by the freezing process, pipes being put in from 5 to 7 ft. apart in a circle around the proposed shaft driven 102½ ft. to rock and 5 ft. further into the rock itself, which, from the bore-hole indications, was supposed to be solid. A freezing mixture, at a temperature varying from 5° to 7° below zero, was circulated in the pipes for a period of about seven weeks, when the first shaft's caisson reached rock which, instead of being solid, was found fissured for 18 ft. below its surface, and with a large flow of water from the fissures.

"With this information, the Mt. Lookout Coal Company, decided that it would be impossible to succeed with the freezing process, with pipes extending only 5 ft. into the rock, so abandoned the attempt and successfully sunk the second shaft with a pneumatic caisson, finding rock at 102½ ft., as above, but only succeeding in making a water-tight joint in solid rock at a depth of 140 ft. below the surface, the fissured rock extending in this shaft for about 35 ft. below the rock surface."

"While considerable time elapsed between the cessation of the freezing and the sinking of the caisson, the ground passed through is said to have been quite well frozen, and Mr. Crawford gives as his opinion that had it not been for the fissured rock the freezing process would have been a success."

Sulphur Mine, Calcasieu Parish, Louisiana.—For many years attempts have been made by various companies to sink a shaft to the rich sulphur deposits occurring in this parish, but all have failed.

In 1886 the National Sulphur Company proposed to use the Poetsch process. It appears, in the following quotation from a recent letter of Mr. M. F. Kerr, Assistant State Engineer of Louisiana, that no actual work was done.

"No plant for operating the process was ever installed at the Sulphur Mines, in Calcasieu Parish. Only the right to operate was

acquired by myself and associates at the time, and nothing more than an examination into its merits as applied to that locality looked into, as explained in the article to which you refer.

"The conclusion was at the time arrived at that the process was eminently fitted to accomplish the objects in view, but a failure to capitalize the enterprise finally caused us to abandon the project and the process was not put into test there."

The article mentioned in the quotation is one by Mr. Kerr, in the *Journal of the Association of Engineering Societies*, Vol. XXVIII, 1902, page 90. It contains a very interesting account of the various attempts to mine sulphur in this locality.

The Scientific American, in Vol. 73, page 388, and again in Vol. 75, page 280, states that the refrigerating plant was installed, but that congelation was not successful.

Harlem Speedway.—The Engineer, of London, June 28th, 1885, page 556, states that Sooysmith and Company are attempting to freeze a bed of quicksand to be penetrated by the excavation for a retaining wall. The depth of the excavation is about 40 ft. A row of 4-in. pipes is sunk, the pipes being 3 ft. apart. Inside the 4-in. pipes, smaller pipes are placed, through which compressed air (the freezing medium) is conveyed to the bottom of the large pipe. No other information, to indicate the success or failure of the project, has been found.

Lift at Fontinette.—In an abstract in the *Minutes of Proceedings* of the Institution of Civil Engineers, Vol. CXXIV, 1896, page 499, the adoption of the Poetsch process for the repair of the cylinder pits of the canal lift at Fontinette is noted.

The *Journal* of the Iron and Steel Institute, No. 1, 1897, Vol. LI, states that the process was applied successfully.

Shaft near Eygelshoven, Province of Limburg, Belgium.—Brief abstracts from *De Ingenieur*, published in Rotterdam, state that the freezing process had been adopted in several instances for sinking shafts in the vicinity mentioned. The article, apparently, is quite complete, and might afford considerable information if translated. The date of the article is 1901.

Shaft of the Ascot Deep Leads Company near Ballarat, Australia.—Mr. F. D. Johnson* states that:

"Some twenty years ago the diamond drill in passing through the basalt into 'drift' found the hydrostatic pressure sufficient to eject

* *The Mining Journal*, Oct. 25th, 1902.

water and sand above its derrick, or about 450 ft. This pressure has been considerably reduced by pumping in other shafts miles distant. The above-named Company is, for the first time in Australia, trying to get through a not very thick layer of drift below the basalt by employing the freezing process or Poetsch method. At the date of writing there seems to be a little doubt as to its complete success, owing, it is said, to the great pressure of water still present there."

Brussels Railway.—Mr. A. Gobert * states:

"Very many sinkings by the freezing process are contemplated in Belgium, and it was expected that the soil of Brussels would be frozen for the line of railway between the Nord and Midi Railway Stations. The Government had consulted the writer and he had given them a complete report upon the subject."

Empelde, Germany.—The Colliery Guardian of August 7th, 1903, page 314, incidentally, mentions the use of the congelation process by the Schalken, Gruben und Hüttenverein at Empelde, near Hanover, in 1899. No particulars have been found.

Pennsylvania Railroad Tunnel Under the Hudson River.—From time to time it has been suggested that the freezing process could be used to advantage in constructing tunnels under the Hudson River. Since the Pennsylvania Railroad tunnels have been projected, plans worked out in some detail have been published in the technical papers.

Shafts Sunk by Gebhardt and Koenig.—In the advertisements of this firm they claim to have completed successfully the following shafts:

Two shafts for the Société Anonyme des Charbonnages, Willem Sophia, in Spekholzheide (Limburg, Holland).

One shaft for the Vereinigungs Gesellschaft für Steinkohlenbau, in Wurmrevier, zu Kohlscheid.

One shaft for the Gewerkschaft Braunkohlenbergwerk, Consol Sophie, near Wolmirseben.

One shaft near Gusten für die Herzogl. Anhalt Regierung.

Two shafts, 5 m. diameter, for the Consol Alkali Works at Westeregeln.

One shaft for the Con. Braunkohlen Mine, near Atzendorf.

One shaft in Essen, on the Ruhr.

One shaft, 147 m. deep, 6.1 m. diameter, for the plant Auguste Victoria, at Recklingshausen.

No further particulars are available.

* *Transactions*, North of England Institute of Mining and Mechanical Engineers, Vol. LII.

Authorities.—The data in this paper have been gathered from the following publications:

Allgemeine Bauzeitung.
Annales des Mines.
Berg und Hüttenmännische Zeitung.
Bulletin de la Société de l'Industrie Minérale.
Colliery Guardian.
Engineering (London).
Engineering and Mining Journal.
Engineering News.
Glückauf.
Iron and Coal Trades Review.
Journal of the Association of Engineering Societies.
Journal of the Iron and Steel Institute.
Journal of the Western Society of Engineers.
Le Génie Civil.
Mining Journal.
Minutes of Proceedings of the Institution of Civil Engineers.
Oesterreichische Zeitschrift für Berg und Hüttenwesen.
Proceedings of the Institution of Mechanical Engineers.
Proceedings of the South Wales Institute of Engineers.
Railroad Gazette.
School of Mines Quarterly.
Scientific American Supplement.
The Engineer (London).
The Engineering Record.
Transactions of the Federated Institute of Mining Engineers.
Transactions of the Mining Institute of Scotland.
Transactions of the North of England Institute of Mining and Mechanical Engineers.
Zeitschrift des Vereines Deutscher Ingenieure.

A list of these authorities, with details as to year, volume, page, etc., for each mine, shaft, or other work described, is filed in the Library of the Society, where it may be examined by anyone who is interested in the subject.

Vol. XXX. JANUARY, 1904. No

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A DESIRABLE METHOD OF DREDGING CHANNELS THROUGH RIVER BA

Discussion.*

By Messrs. E. L. Corthell, A. W. Robinson and L. J. Le Conte.

Mr. Corthell. E. L. Corthell, M. Am. Soc. C. E.—The speaker desires to s at the outset, that he is not expert in the details of dredging, and this paper could have been discussed much better by, say, F Maltby, M. Am. Soc. C. E., Superintendent of Dredging Operat for the Mississippi River Commission; or by Professor V. E. Timo M. Am. Soc. C. E., from whom it is hoped a discussion will be recei as he has been a strong advocate of dredging in Russia; or by mem of the Mississippi River Commission, who have paid great atten to the subject for many years, and have evolved the methods no use on that river.

The speaker agrees with Mr. Hering, and with the author, that general principles, a dredged slope in the direction of the cur would be better than a slope against the current; but, how far th practicable, and how far, really, in practice, it will answer the pur of preventing deposit in the cut, is somewhat doubtful. It is a q tion to be solved by the results of actual practice, and these are given by the author. Evidently, it is a theory which the author advanced from his own observations, and, as far as it is based on perience, it might well be adopted.

* Continued from December, 1903, *Proceedings*. See October, 1903, *Proceeding* paper on this subject by S. Maximoff, Assoc. M. Am. Soc. C. E.

Mr. Corthell.

It is germane to the subject to take up the more general question f dredging, not in the way of a discussion of the method proposed by he author, but as developing this very important method of improving ivers.

The subject has an important history, dating back to 1880 or 1881, ot only in this country, but in Russia and other countries, and old nethods are being laid aside. What was considered best twenty-five ears ago, in dredging or in river improvement, has, by long experience, nd by dealing with great forces, been subjected to change. During he past three or four years, the experience, observation and interest f the speaker, as an engineer, have been largely upon these subjects f river and harbor improvement, which he has been obliged to tudy, and has been called upon to give his opinions to a foreign overnment.

Knowing quite well what has been going on in Russia, through a uite intimate acquaintance with Professor Timonoff, who was one of he originators of this method on Russian rivers, the speaker has arved at some conclusions, and will give a general *résumé* of the history f dredging, because it is a very important subject, in respect to the avigation of great rivers, not only those of the United States and Russia, but those of other countries.

In the first place, in reading this paper, one is impressed by the imilarity between the Volga and the Mississippi. They are of about he same size; the navigable length is about the same, about 16 000 niles; the maximum discharge of the Volga is nearly 1 500 000 cu. ft. er second, which is about the same as that of the Mississippi, although here have been extraordinary conditions in the latter when the discharge has been greater; the rise and fall of the water in places is pproximately the same, that of the Mississippi being a little greater, erhaps; and also the conditions of the bars and the depth over them, lthough the minimum is less on the Volga. The general features of he two rivers are very much alike; one emptying into an inland sea, nd the other into the ocean—or the Gulf of Mexico. Thus the lessons earned on the Volga can be applied to the Mississippi and to other reat rivers.

Another very interesting fact relates to the number of miles of avigable water in Russia. The author has given it as about 35 000 niles. Professor Timonoff, in a paper a few years ago, stated that here were 100 000 km. (62 000 miles) of navigable waterways in Russia, but, no doubt, he included Siberia. Thus, comparing the United States and Russia, as to these features, there is more or less imilarity.

In reference to the changes which have taken place in these two ountries during the last twenty years, by experience, in opinion and n methods, if examined and compared carefully, it will be seen that hey have kept pace with one another.

Mr. Corthell. An examination of Table No. 6 shows that the appropriations for permanent works have been decreasing, particularly within the last three or four years, since very large dredges have been put in operation. This table also shows that the sums expended on dredging have been increasing, and that large amounts are still required to maintain the permanent works, or old works constructed some years ago. All this indicates that the tendency is toward a larger amount of dredging, as the author has stated.

Three or four years ago the speaker went to Argentine to advise the Government as to river regulation, and then had found it necessary to study what had been done on the Mississippi, in reference to dredging, as he had never studied it before. Taking the reports of the Mississippi River Commission, from 1881 to 1900, he had examined them carefully; taking up, first, the engineering work; secondly, the constructive work; and thirdly, the results of experience and the change of opinion. These were the headings under which the investigation had been made. Probably two or three months of study were spent in getting at the results of the experience on the Mississippi, and, in glancing over the many pages of that investigation and the notes taken, one can see the changes of opinion, due to experience, taking place, just as they have been taking place in Russia. If one should examine the reports of the Commission for the last three or four years he would see that it is coming to the principle, enunciated several years ago by French engineers, and, following them, by Professor Timonoff, which is, to improve these great rivers by "dredging and the attraction of the waters"; that is, to open channels in the direction in which the waters will flow most easily, and in that way draw the water at low river through these artificial channels for the improvement of navigation, and with the hope and expectation that they will continue in that direction, approximately, during the high-water season, and thus, eventually, make permanent channels, without any great expenditure on permanent works.

In the speaker's opinion, the subject is of great importance, because, from its development, lessons can be drawn from the work being done in other countries.

The following quotation is from a paper by Professor Timonoff to the VIIIth International Congress of Navigation, held at Paris in 1900, in which is laid down the law governing the case. A foot-note in that paper refers to a paper, presented to the Maritime Congress of 1889, by M. Pasqueau, Chief Engineer, Ponts et Chaussées, on the "Port of Bordeaux and its Channels":

"Quite a wrong generalization of the law of hydraulics is therefore made in arguing on these rivers (the Garonne and similar rivers), as if they were mere ditches with trapezoidal section, of which one bank can influence the opposite bank. These rivers are so very wide and shallow that the action of the banks, in fixing the navigable channel,

may be considered as of no importance. The navigable channel makes its way along this expanse of water without being much influenced by the banks, obeying another law, quite as general, but which is often lost sight of. I call this law, the law of the attraction of waters, and I explain it as follows: Mr. Corthell.

"Let us suppose a sheet of water, very wide, with rectilinear or other banks. If there exists, in Section *a b*, a ditch on the right bank, more water will pass in *a b*, along the right bank, than along the left bank. If a natural or artificial channel, *i k*, exists further along on the left bank, more water will pass on the left than on the right. Therefore the channel, *i k*, will determine, in the direction, *b i*, an oblique current which will carry a part of the waters from the right bank on to the left bank.

"I state this fact in saying that the channel, *i k*, will attract the waters to the left bank, and that the waters, once thrown on to this bank, will remain there, whatever be the form of the bank, as long as they will not be attracted or drawn in another direction by a natural or artificial channel established on the other side. I conclude from that, that in those rivers permanent results can be obtained by dredging directed intelligently. The effect of this dredging is, not only to take away a deposit susceptible of reforming again, but really to produce a permanent modification of the bed itself."

Professor Timonoff proceeded then as follows, in the foot note:

"Regarding this same law, we find in the discussions which followed Mr. Pasqueau's report, the following discussion of the paper by Mr. Vauthier, General Engineer:

"'What precedes brings us to Mr. Pasqueau's second question, and I agree with him as to the efficiency which, in numerous cases, a pre-existing navigable channel may have in assuring a good *régime*.

"'It is certain that by longitudinal excavations, carried out intelligently, the currents may not only be attracted into a definite region of the bed, but be maintained there; and I am prepared to acknowledge that, as regards dredging in river beds, too much stress has been laid on this objection, regarded as irrefutable, that the natural action which had previously modeled the bed, would succeed, sooner or later, in re-establishing things in their former state. First, it is not true of the case in which the dredge makes matter disappear which was not naturally underminable; and it is also often false, as a general rule, because the new conditions created may, co-relatively, determine up- and down-stream changes, suitable for assuring the maintenance of dispositions artificially realized.'

"In 1894 another French engineer, Mr. Gerardin, at the Congress of Navigation at the Hague, brought up the same subject and dealt with it in very nearly the same way, and he was one of the earliest who had brought forward this general method, of dredging, instead of building permanent works.

"The Mississippi Commission, in their report in 1898, used the following language in closing one of the paragraphs on this subject: 'Those principles, which seem to be most applicable to our temporary works, as well as to permanent low-water improvements, are well stated by Mr. Gerardin, Engineer of the Ponts et Chaussées, in a paper on the training of rivers at low water, read at the Sixth Inland Navigation Congress, held at the Hague in 1894.'"

From these extracts it can be seen that the subject has been discussed for some time by very prominent engineers, so that it may be con-

Mr. Corthell. cluded at the present time that it is not a matter for further discussion. It is a method which experience has taught is the best for improving the navigation of rivers like the Mississippi, the Volga, the Paraná, the Rio de la Plata and others of that nature.

In 1898, Professor Timonoff, in an important paper,* wrote:

"By what means can we improve the navigable conditions of great rivers such as the Dnieper, the Volga, the Lower Danube, the Mississippi and others? Can we not find a method more sure and less costly than the methods of improvement as they are applied to-day? The author has sought to solve this problem, and a long analysis of the works of improvement executed in France, in the United States, in Germany and Russia and other countries, has led him to formulate and to propose a method which he calls 'Regulation or Improvement by Dredging and the Attraction of the Waters'; a method taught particularly by the theoretical researches of the French scientists and the experiments in dredging by American engineers."

And then he states, further:

"And this is what it consists of, viz.: The waters are not to be directed by force over the bars which are to be improved; on the contrary, we are to preserve those bars from the danger of being too deeply cut, as they are often, by permanent works. And the secondary channels are not to be closed, at first, at least, and not until, by means of dredging, the proper location of the channel has been determined. We commence, after a very careful study of the local conditions of each of the bars, a strong mechanical dredging in the direction of the channel considered the most suitable and the most convenient. The width of the cut is reduced to the minimum. The depth, on the contrary, should be made as great as possible, and the mechanical dredging itself is a means of improvement, or regulation, independent of its importance, and so much the more capable of making immediately a depth necessary for the navigation. And, finally, the cut made across a bar modifies the conditions of the movements of the waters, and here the law of the attraction of the waters applies."

The foregoing quotation is given to show how the subject has grown and has been moved on in this direction by the French and Russian engineers.

Last year, the speaker was requested, by the Minister of Public Works of Argentine, to make a special examination, during the past winter, of the results of works on the Mississippi, and the methods pursued there; and, also, to learn the opinions of the engineers and make a report on the subject. He has done so; and, without going into all the reasons or the facts which had led him to his conclusions at that time, he would quote the closing paragraph of that report. This had been made after an examination of the improvements and the dredge boats on the Mississippi, and talking with the Superintendent of Dredging, Mr. Maltby, of Memphis, where the dredging fleet was laid up in winter quarters. It was as follows:

"Generally, it may be remarked as a conclusion, with respect to the whole subject of operations on the Lower Mississippi, after many

* *Annales des Ponts et Chaussées.*

years' experience, and the expenditure of probably $40 000 000, on a river like this, the best practical plan is to dredge the channels at low water, and do only such construction work as is necessary at important points to prevent the river from making radical changes, and not to attempt to confine the channel by contracting works, as the interest on the money so expended will more than do all of the dredging work required to make and maintain the channels during the navigation season of low water. In other words, the principle, enunciated by Professor Timonoff, of 'attracting the waters' is the true principle of improving such rivers as the Mississippi and the Paraná." Mr. Corthell.

The report proceeds as follows:

"The latter river (the Paraná) is a much more favorable one, in respect to its conditions, than the Mississippi, for the reason that it carries only about one-tenth of the sediment carried by the Mississippi. The channels, once made in the line of the strongest currents, will not only maintain themselves for, probably, several years, but will be enlarged by thus directing the current through them. Even on the Mississippi, where immense quantities of sediment are brought down in the annual floods of the river, the channels are found to be much better maintained than was expected of them. In fact, most of them, when properly laid out to receive the current in good line, have largely maintained themselves, so that the dredge work is really becoming less and less; so that we may say that experience here and on the great rivers of Russia has demonstrated the fact that in making and maintaining river channels, the dredge work should predominate, although there are many cases on all these rivers where guiding and controlling dikes and protection of banks may be found useful and often necessary."

On the Argentine rivers, particularly at the head of the Rio de la Plata, there are found practical illustrations of what will result from dredging. The dredging, however, was not done by a dredge, but, after very careful examination of the bottom and of the direction and velocity of the currents, the steamers had been sent through a certain channel, marked by luminous buoys, so that by day and by night they had passed over the same ground exactly, and thus the depth over a difficult bar had been increased from 14½ to 19 ft. within two years.

This very satisfactory result and the results in other countries led the Argentine Government to adopt the same method on probably one of the most troublesome bars to be found anywhere for ocean navigation, the Punto Indio Bar in the Lower Rio de la Plata, which is 24 miles wide, on which there were only 19 to 20 ft. of water, and where the river was 35 to 40 miles wide. The plan now being carried out, after examining all the conditions carefully, ascertaining the velocities and directions of the currents, and examining the material in the bed of the river, is to buoy, by light-boats and luminous buoys, a channel over the entire bar. The buoys and light-boats can be seen from one another. It is the expectation, and the speaker believes it to be well grounded, that within, say, three or four years after this route of

Mr. Corthell. navigation has been used by deep-draft steamers, there will be a very considerable increase in the depth of water.

There are many rivers in the world where it is impossible to build constructive works, and the Rio de la Plata is one of them. When the speaker went to Argentine he believed that the principles which had been applied and the methods which had been used on the Mississippi, that is, guiding works, dikes, dams, etc., might be used on the Paraná and the Rio de la Plata, but when he stood in the presence of a river 30 to 40 miles wide he made up his mind that there must be a method better than such a costly one for a government which had very small means for carrying on costly works; and it was with that before him, and with the request made to give an opinion and make plans, that he had made such a very careful study of the work on the Mississippi and in Russia, and he had become satisfied, from that study and from some practical experience in such work, that the most feasible plan for navigation, and for the exchequer of the government, was to carry out the principle of "dredging and the attraction of the waters," enunciated by Professor Timonoff.

On the Volga there is one powerful hydraulic dredge, designed by Mr. Lindon W. Bates, an American engineer, and the cost of the work done by it, compared with the cost of work done by other dredges, is given in an official report, by the Engineer of the Russian Government, for 1901 and 1902. In 1901 the cost, including all expenses—probably, however, not including depreciation and interest—was 6 cents per cubic yard, on a very large quantity of work, whereas the cost by the ordinary pump dredge on the Volga had been about 10 cents. The report states that the total quantity taken out by the Bates dredge in 1902 was 2 982 598 cu. yds. at a cost of 3.6 cents per cubic yard.

Mr. Robinson. A. W. Robinson, M. Am. Soc. C. E.—Mr. Maximoff's paper is a very useful addition to the records of the Society on account of the data it contains relating to the navigation interests of, and the means used to improve, the rivers of Russia. The nature of these rivers and the conditions of navigation upon them are not unlike those prevailing in this country, and Mr. Corthell has drawn attention to the great similarity between the Volga and the Mississippi. Each river drains a vast extent of interior country and is subject to a spring rise of from 20 to 40 ft., or more; and each carries a large quantity of alluvial matter which forms bars obstructing the channel at low water. Each, also, is ice-bound in its northern part during the winter, and the low-water navigation depth in each is similar. The method of improving the Volga, as described by the author, is different from that used on the Mississippi. On the Volga, the author states that the dredges are of the elevator type, from which the material is pumped away a short distance. In dredges of this type, one set of machinery excavates and lifts the material and a separate set of machinery dis-

oses of it. In view of the double duty thus performed by these redges, the quantity of work done and the cost, as given in the paper, re most creditable, and lead one to think that, if powerful hydraulic redges of suitable design were adopted, which could perform the ouble operation of excavating and disposing of the material, still etter results could be obtained. Mr. Robinson.

The author states that the average cost per cubic yard of material xcavated and carried away was 9.81 cents, while for single dredges it veraged from 2.70 to 48.40 cents. The cost of dredging on the St. awrence River, where the speaker has been doing some work lately, less than that. In the report of the Chief Engineer of the Depart- ent of Public Works of Canada for the fiscal year ending June 30th, 902, the cost of dredging on the ship channel of the St. Lawrence, etween Montreal and Quebec, is given in detail for the various locali- es, as executed by the various dredges. On account of the wide versity of material, this cost varies from 1.75 to 36.69 cents per cubic ard, the average of the whole being 4.58 cents. This is for operating xpenses, including ordinary repairs, but not interest or depreciation. he dredges by which this work was done are of the elevator type and e hydraulic type, but not both combined.

With regard to the arguments adduced by the author in favor of s proposed method of cutting a sloping channel, they seem to be asonable. There is no doubt about the scouring action of the water a dredged cut. This is due to the more rapid current. Experience the Mississippi and on the St. Lawrence shows that the current ill flow more rapidly through the increased section of a dredged cut an over the shallower portions of the river. The speaker thinks at the most that can be said for the scouring out of the dredged rts, in an alluvial river subject to wide changes in all its conditions, that the scouring action delays the filling-up process, but does not revent it. There are exceptions to this rule, as scouring action is metimes found to increase the depth for a time. The rules govern- g sand bars are like the rules for the pronunciation of the English nguage—there is no rule without an exception.

Like Mr. Corthell, the speaker is an advocate of dredging the annels of alluvial rivers in such a way that the scouring action of e water will aid the artificial forces. Scouring action alone, by eans of training works, has not yet been found sufficient, and, in e majority of cases where dredging has been resorted to, it has ac- omplished the desired result. Contrary to the general impression, a redged channel through a sand bar is not soon obliterated, but may xist for a considerable time and survive a flood season with only inor changes.

As to the special method of dredging which the author proposes, e speaker is unable to agree with him, or with the opinion expressed y Mr. Hering, that the slope of the bottom will aid the movement of

Mr. Robinson. the sand. The speaker does not think that a slope of about 4 ft. in 1 000 ft. is enough to produce any perceptible effect. The movement of the sand along the bottom is not due to such an inclination, because it is too slight. It is due to the movement of the water, and is not like rolling down hill. In fact, if the section of the cut thus produced is greater at the lower end one would think it would make the velocity less, and, consequently, the scouring of the sand would be less at the lower than at the upper end. There certainly will be an increased velocity in the dredged cut, as compared with the remainder of the section of the river, as has been already noted.

The author states that he finds the power on the centrifugal pumps to be insufficient. In the outline drawing of the dredge (Plate LVII*), the engines for driving the buckets of the elevator part and those for driving the centrifugal pump are both shown as being the same, and, presumably, are engines of the same size. The speaker's experience leads him to believe that the power for driving the centrifugal pump on a dredge of this type should be two or three times that required to drive the elevator chains and buckets.

It is interesting to observe the type of river steamers illustrated in the paper, and compare the practice with that on the Mississippi. The practice on Russian rivers is to separate entirely the passengers and freight, whereas, on the Mississippi, most steamers carry both passengers and freight. The trim little passenger vessel illustrated on Plate LIII* does not appear to have any self-contained gangways, for approaching a bank at any point, which are such a conspicuous feature of the Mississippi boats.

It is to be hoped that Mr. Maximoff will try his experiment and then give the Society the result.

Mr. Le Conte. L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The tabular statements submitted by the author show conclusively the wonderful growth of inland navigation in Russia in the past decade, more particularly on the Volga, the principal river in Russia.

The author gives the detailed drawings of the typical dredge now used on the Volga, which proves to be a combination machine, an endless-chain bucket dredge with hydraulic attachments instead of scows for disposing of the spoil. Machines of this type have done very good service in past years, but were discarded some time ago for those of a better type, which are now in general use. Those of the new type have greater capacity for work, in a given time, with lower operating expenses, and, at the same time, with much lower expenses for repairs, so that the unit cost of doing work is very much reduced.

The writer refers to hydraulic dredges of the latest type, fully equipped with suitable cutting apparatus adapted to encounter material of all classes.

---

* *Proceedings*, Am. Soc. C. E., for October, 1908.

In Table No. 8, the dredges named *Volgian 7* and *Volgian 8* are hydraulic dredges with capacities of 1 500 cu. m. per hour. These, no doubt, are of the type the writer refers to, and it is natural to suppose that each is provided with a full set of cutters to enable it to cope with material of different classes. Mr. Le Conte.

It should be mentioned that machines of this class are sometimes limited in their usefulness, because of the fact that it is absolutely necessary to have a suitable dumping ground upon which to place the material excavated. In all river work, however, this dumping ground feature is generally available, so that this requirement is always fulfilled.

The writer was surprised not a little to note the high cost of dredging on the Volga, and, as no mention of the character of the material was made, the inference is that it was coarse and heavy. This view was not upheld, however, by noting the flat slopes per mile, viz.: 2.8, 3.4 and 2.0 ins., respectively, and this precludes the possibility of much heavy material.

The average cost, 8.5 cents per cubic meter, together with the average contract-hour capacity, 337 cu. m., do not speak very well for the efficiency of the dredging fleet now in use, but leave much room for improvement. At 8.5 cents per cubic meter, 337 cu. m. would cost $28.65 per contract-hour, which seems to be excessive for a grand average. With machines of the latest type much better results are easily obtained. A 1 200-H.-P. dredge, complete, in every respect, and ready for active service, costs not more than $150 000, and it can generally be depended upon to do the work mentioned in Table No. 9, in material of different classes, at the stated unit prices.

TABLE No. 9.

Character of material.	Engine-hours per month.	Operating expenses and repairs per month.	Quantity of material excavated per month, in cubic yards.	Cost per cubic yard, in cents.
Very hard sandy clay and cobblestones	500	$6 000	20 000	30
Sandy clay	500	5 700	25 000	23
Tough clay	500	5 300	30 000	18
Shingle	500	5 000	35 000	14
Coarse sand	500	4 750	40 000	12
Sand	500	4 500	50 000	9
Stiff mud	500	4 250	100 000	4
Soft mud	500	4 000	200 000	2

Table No. 9 is submitted with the distinct understanding that it is only intended to give general results; therefore, it is to be used with a great deal of discretion. Of course, in ordinary every-day practice,

Mr. Le Conte. these different classes of materials are nearly always intermixed, more or less, which fact greatly facilitates dredging operations. For example, sand largely mixed or interstratified with clay or mud can easily be dredged for 3 to 4 cents per cubic yard. These conditions prevail on river bars nearly everywhere, a fact too often overlooked. On the other hand, while clean sand works very well with a moderately short pipe line, yet the difficulties multiply enormously when it has to be forced through a long pipe line. This is due to the fact that the sand separates from the column of water and runs along the bottom of the pipe with an entirely independent flow of its own. The water and sand, in their passage through the pipe line, refuse to mix. Increasing the speed of the pump, by which the mean velocity of discharge is increased, seems to have little or no effect in remedying the trouble. Both the foregoing facts affect the unit prices given in Table No. 9 quite materially, so that in each case all the existing facts and conditions must be known before any comparisons can be drawn.

The writer was much impressed by the author's proposed scheme for dredging channels through river bars. The general custom in America has been to make the cut uniform in width and depth, and locate it where the axis of the current seems to settle for the season. The writer thinks that there is much in the suggestion advanced by the author. Everything seems to point that way.

Vol. XXX. JANUARY, 1904. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE BREAKWATER AT BUFFALO, NEW YORK.

Discussion.*

By Messrs. Thomas D. Pitts, William T. Lyle and D. E. Hughes.

Thomas D. Pitts, Assoc. M. Am. Soc. C. E. (by letter).—The writer draws attention to the following points: Mr. Pitts.

In the first place, the capping stones of the stone breakwater appear to be quite regularly rectangular in form and of about 6 to 7 tons weight; and they are laid on the rubble mound without other bond than that given by the friction of one block against another. Records of experience abroad show that when a stone in such a pavement is removed from its place the whole pavement goes to pieces very rapidly. It seems to the writer that a comparatively small movement of either harbor- or lake-side angle stones might so disarrange the capping stones immediately above that they would be torn out by the waves, with the result that a large section of the pavement would be stripped from the core; and he would be much interested to know whether any indications of such a future mishap have been discovered. He would also like to know if it has been observed that the ice formation in winter has had any tendency to lift the capping stones from their beds.

In the second place, the sections of the breakwater (Fig. 22) showing the original section as designed and the section after settlement

* This discussion (of the paper by Emile Low, M. Am. Soc. C. E., printed in *Proceedings* for November, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to February 27th, 1904, will be published subsequently.

Mr. Pitts. of the portion which failed, have almost exactly the same area above the lake bottom. This, to the writer's mind, indicates, not that the rear portion of the breakwater settled bodily into the soft clay bottom, but that it slid toward the harbor side, removing the support of the center section, which, of course, then settled down. The sliding was probably started by some slight settlement of the breakwater into the clay, but, from the drawings, it seems to the writer that it was probably more largely due to an insufficient mound or retaining wall of rubble at the toe of the rear slope, to too steep a slope of the harbor side of the breakwater, and to the use of gravel in the hearting. It seems likely that the latter was a very important factor in the settlement, because gravel, on account of its form, does not pack as solidly as rip-rap or rubble, especially when washed free from a portion of its matrix, as must have been the case with this gravel, dredged from the bed of the Niagara River. With regard to the portion of the breakwater first built, in which no settlement has taken place, its stability seems to be accounted for sufficiently by the more solid foundation which has prevented the initial settlement under wave action, which settlement would start the sliding; and it may be, too (it does not appear from the paper), that, under the part of the breakwater which sank, the top layer of clay is softer, and the coefficient of friction therefore much less than under the older part which has remained intact.

Mr. Lyle. WILLIAM T. LYLE, Assoc. M. Am. Soc. C. E. (by letter).—The history of Buffalo Harbor is incomplete without some description of the celebrated Black Rock controversy. The writer is in possession of letters, written by DeWitt Clinton, Myron Holley, David Thomas and Benjamin Wright, relative to this dispute; and these, supplemented by the reports of the Canal Commission and other official publications, throw considerable light on the subject in question.

Along with the construction of the Erie Canal came a pressing need for a suitable port at the eastern end of Lake Erie. The choice of the terminus of the canal lay between two places; one, Buffalo, and the other, Black Rock. These places were about 4½ miles apart. There were five principal projects advanced. The three of least importance will be mentioned first. The dispute, in reality, lay between Projects 4 and 5.

1.—This plan provided for a harbor in the lake where the line of the main street of Buffalo intersected the beach. The harbor was to be formed by building a pier in a westerly direction and then extending it northerly parallel to the shore. The width of the harbor, from east to west, was to be 1 000 ft.

2.—It was proposed to excavate the neck of land near the ferry, and enter Buffalo Creek from the lake along the slip. This plan met with little favor.

3.—Another plan was to construct a large harbor at Black Rock by building a pier from Bird Island to Squaw Island, thence to Strawberry Island, thence to the head of Grand Island, and closing the opening between Grand Island and the eastern shore by a dam at White Oak Bluffs. This plan, by reason of its enormous cost and the likelihood of international difficulties, was soon abandoned. Mr. Lyle.

4.—The fourth plan differed from the third in calling for the dam at the lower end of Squaw Island instead of at White Oak Bluffs. The north and south pier was to be about 500 ft. from the shore, and, at the upper end of Squaw Island, was to meet an embankment extending along the eastern shore of this island to the western end of the dam. This plan was worked out by James Geddes. In the plan adopted finally the pier was built nearer the main shore. A slight modification, and one which did not affect the embankment and dam already mentioned, was to turn the pier, at right angles with the shore, about 800 ft. north of Bird Island, thence to extend it two-thirds of the way across the east channel and thence at right angles down stream to the south end of the embankment. A pier built in this manner would obstruct the flow of the Niagara River greatly, and the modified plan was discarded.

The Black Rock project met with considerable favor, and was championed by General Peter B. Porter, a citizen of Black Rock, and his associates. They contended that in case of a storm, a harbor at Black Rock would be more easily entered than the one at Buffalo, which will be described later; that the canal would be shortened considerably by deciding in favor of Black Rock; that the harbor would be much larger than the one at Buffalo; and that hydraulic power of immense value would be developed. They maintained that Buffalo Creek brought down the sand that formed the bar at its mouth, and that Buffalo Creek was eminently unfit for a sheltering place.

The objection to the Black Rock plan was largely on account of its excessive cost. It was urged that in case of hostilities with the British, the harbor would be useless as long as they held possession of the opposite shore; and that in time of winter the floating ice hurried along in the swift current would demolish the pier. The prevailing winds would also interfere decidedly with the exit of vessels in attempting to reach Lake Erie. Another objection to the Black Rock Harbor arose from the fact that the bottom was rocky and afforded poor anchorage. It was also argued that the protection of Black Rock against the violence of the waves was due to the rapids in the Niagara River; and that this advantage would be partially lost should the harbor be constructed and the elevation of the water surface at Black Rock be raised to the surface elevation of Lake Erie. Since, in accordance with this plan, the canal was to be supplied with water from Black Rock Harbor, it was thought by many that it would be somewhat dangerous to stake

Mr. Lyle. the welfare of the canal on an artificial, and in some respects an experimental, construction. The work there would require much more time for its execution than that at Buffalo, and the time element was a very important one in view of the public clamor for the canal's early completion.

5.—A plan which did not thoroughly meet the approval of the Canal Commission, but which was endorsed by Governor Clinton and one of the commissioners, provided for the development of the mouth of Buffalo Creek as a receiving basin which would be both cheap and adequate. The plan was prepared by David Thomas, who, in 1820, was appointed Engineer of the western section of the Erie Canal, from the Genesee River to Lake Erie, and who was continued as Chief Engineer of the same section by a resolution of the Canal Commission passed in March, 1822. From his report, printed in the "Public Documents relating to the New York Canals," published in 1821, are copied the following extracts:

"The depth of water in Buffalo Creek is sufficient for a harbour. In taking soundings almost up to the ferry (which is 1 mile from the entrance) the least depth observed was 11 ft., and this only in two places; but the common depth up this stream is from 12 to 14 ft. About 50 rods above the mouth of Little Buffalo, we found 17 ft., and a few rods within that part of the entrance which is obstructed by sand, we found 19 ft. No injury to this channel need be apprehended from depositions of either sand or mud.

"The breadth of this creek, just above Little Buffalo, is full 16 rods; but 35 rods above, the breadth is only 12 rods; and the calculation of two triangles, taken further up the stream, at the respective distances of 40 and 70 rods, gave no material difference.

"The shore is bold, and very little of the channel need be occupied by wharves.

"It appears that after freshets in this stream, the entrance is deepened from 12 to 15 ft.; but the common current is so sluggish as to permit the first gale to drive sand and gravel into it from the south. As the obstruction to navigation only originates from this simple cause, a remedy equally simple will be sufficient, and may be found in a pier or mole, as heretofore proposed by William Peacock. I think, however, that both its position and construction should be different.

"I would propose to commence it at the lighthouse, because there is no firm ground further north, and the work ought to be secure in the rear. Thus, if we began half way down to the point (which is only a loose bed of sand and gravel), Buffalo Creek might break through between the pier and the lighthouse. On the contrary, if we commence it above that building, the entrance of the creek will be less protected from northwesterly storms; and this view will be important whether we consider the entering of vessels or the drifting of sand into the channel. It appears that the direction of the gale shapes the gravel point, as its course on William Peacock's map varies considerably from its present position.

"The reason for locating the pier above the lighthouse was founded in misapprehension. There is no appearance of sand or gravel having ever been brought down by Buffalo Creek."

The foregoing report is dated October 15th, 1819. Mr. Lyle.

It was Mr. Thomas' plan to commence the pier at the lighthouse and extend it North 70°, West 1 150 ft. The pier was to be made of timber cribs; the substructure was to be of round green logs filled with brush and gravel, and the superstructure of squared oak timbers loaded with large blocks of stone.

In a letter to Myron Holley, who was one of the Canal Commissioners, Mr. Thomas writes:

"If it should be deemed the best policy, notwithstanding, to expend the funds of the State in making a capacious harbour, and not to wait 50 years when it may be wanted, still Black Rock is not the place for such an expenditure. In truth, it is the most preposterous location that could be attempted. To make a harbour, worthy of being known as a national work, the site south of the Buffalo pier, originally selected by Joseph Ellicott, is unquestionably the best. At an expense not amounting to one-half of the Black Rock pier, a harbour may be formed in the lake which shall be twice as capacious as the anchoring ground to be enclosed by that work."

An argument in favor of Buffalo Harbor was its protection from storms and its freedom from ice. Mr. Thomas also urged that as the water of Buffalo Creek was much warmer in the early spring than the water in the Niagara River, canal navigation could be opened several weeks earlier if Buffalo Creek were made the terminus. This was afterward found to be the case.

It may be of interest to consider Governor Clinton's opinions concerning the Black Rock project. In a letter to Mr. Thomas, dated July 25th, 1823, he writes:

"The Canal Board have adjourned to-day after affirming their former decision in favor of Black Rock. This has received my decided opposition, and is, in my opinion, totally indefensible."

Again, on June 15th, 1824, he writes:

"The decision in favor of Black Rock is universally condemned, and whatever the motives may have been, the deed itself will stamp the authors with indelible blame."

Again, on the 11th of July of the same year:

"With respect to the Black Rock Harbour (if artificially constructed) I never had but one opinion of its merits—that it will be a total failure unless at least a million dollars is expended on its construction. Time will verify your opinion, and there can be no doubt but that the men who have sanctioned this measure will repent of their folly."

The Black Rock Harbor was built, but it was decided to continue the canal as a branch to Buffalo. The Black Rock undertaking proved a failure. The pier suffered severely from the storms, and the harbor became choked with mud, as has been described in Major Symons' report. After the completion of the canal, the Village of Black Rock gradually declined and was soon overshadowed by its more fortunately situated rival.

Mr. Hughes. D. E. HUGHES, Esq. (by letter).—This paper is very interesting and instructive.

The character of the clay, the cross-section of the mound, and the damage sustained in December, 1902, are matters of great importance for future reference, and there are a few points concerning them which the author has not yet made quite clear.

Fig. 22 shows a narrow berme on the harbor side, with slope of 1 on 1½ below it, while Figs. 18 and 20 show a steeper slope, and practically no berme. The slope, 1 on 1½, is very near the natural slope of rubble in comparatively quiet water, and, taken in connection with the steeper slope above it, would give, in the absence of an ample berme, a combination which, though stable under vertical force alone, cannot have much reserve safety to withstand the resultant of gravity and the force of breakers, whether the latter be considered as acting on the structure as a whole or as a pressure transmitted through the water in the interstices to act on individual stones in the harbor slope.

It is noted that the drawings show that the gravel hearting was built to about its natural slope on the harbor side. A pile of rounded bodies like pebbles, when subjected to a load on top, tends to flatten out; hence, in this case, there would be some horizontal push from the gravel against the rubble armor, lessening its stability. Again, unless the interstices in the rubble be very small, the water in them will be agitated to such an extent, when breakers are high on the lake side, that the gravel, unless very coarse, will seek a flatter slope by running into, and possibly through, the armor. Any such movement in the gravel would rob the superstructure of its support, and the capping stones, like a straining beam truss, or an arch, would produce horizontal thrust, and the weaker abutment—that on the harbor side —would be the one to yield. The paper does not state how coarse the rubble was, nor how fine the gravel.

The author gives a quotation, leaving it uncertain whether or not he concurs in all its statements, in which it is said that "a length of about 1 000 ft. sank into the clay about 10 to 14 ft.," and Fig. 22 shows a typical section before and after the damage. The second section has as much area above the plane of the lake bed as is shown in the first, the loss at the top being fully compensated by the addition to the toe on the harbor side, thus proving, if the drawings be correct, that there was no sinking into the clay, and that the deformation was due to other causes.

Considering the height of the mound, the voids in the stone and gravel, the buoyancy of the water, and the distribution of the pressure over the wide base, the extra load on the foundation due to the structure is less than 1 ton per square foot. The author classified material dredged not far distant as moderately stiff clay, and walls

trenches stood much steeper than 1 on 1. It is not stated r the steepness was limited by the character of the material ne mode of dredging. In either case, such clay would be ex- to bear a random stone breakwater 42 ft. high; hence it would resting to know what comparison was found, by borings or se, between it and the clay along that part of the breakwater uffered damage, also how easily the range piles drove along ne line. Mr. Hughes.

il the light of the final discussion is received, it will seem to ter that the so-called settlement was a deformation due to some iency in the cross-section, and not to any failure of the clay tion.

Vol. XXX. FEBRUARY, 1904. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS.

PLATES.

VOL. XXX. FEBRUARY, 1904. N

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

SUBSTRUCTURE OF MARSH RIVER BRIDGE

By HERBERT J. WILD, Jun. Am. Soc. C. E.

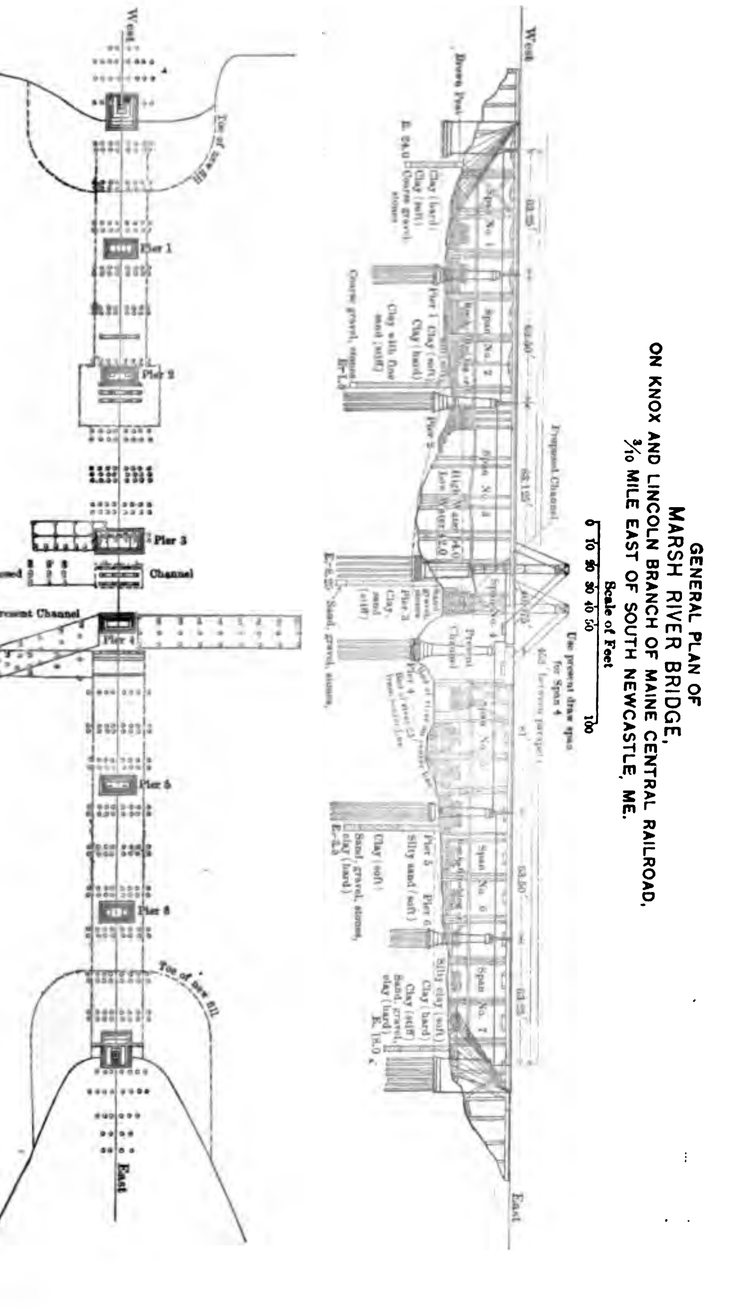
TO BE PRESENTED MARCH 2D, 1904.

The coast of Maine, from the mouth of the Kennebec River to mouth of the Penobscot, presents a series of bays, inlets and estua Indeed, the United States Geological Survey has selected the quadra in which Marsh River appears (the Boothbay Sheet) as an examp typical fiord coast line.

When the Knox and Lincoln Railway was built, in the Seventies, its general direction was parallel to and about 12 distant from the coast. This location made it necessary to cross waters five times in the 47 miles from the Kennebec River to Rockl All these openings were spanned originally by wooden bridges, w have since been fitted with steel swing draws. This paper is a des tion of the substructure of the fourth of these to be replaced modern steel structure.

Marsh River Bridge, in the Town of Newcastle, spans a branch of the Sheepscot River, which derives its name from its b which are the typical mud flats bordered with marsh grass.

NOTE.—These papers are issued before the date set for presentation and discu Correspondence is invited from those who cannot be present at the meeting, and be sent by mail to the Secretary. Discussion, either oral or written, will be pub in a subsequent number of *Proceedings*, and, when finally closed, the papers, wit cussion in full, will be published in *Transactions*.


GENERAL PLAN OF
MARSH RIVER BRIDGE,
ON KNOX AND LINCOLN BRANCH OF MAINE CENTRAL RAILROAD,
3/10 MILE EAST OF SOUTH NEWCASTLE, ME.
Scale of Feet
0 10 20 30 40 50 100
West
East
Pier 1
Pier 2
Pier 3
Pier 4
Pier 5
Pier 6
Channel
Present Channel
Proposed Channel
Span No. 1
Span No. 2
Span No. 7
Use present draw span for Span 4
Clay (hard)
Clay (soft)
Silty sand (soft)
Sand, gravel, stones, clay (hard)

The crossing is practically 600 ft. in width, but embankments have reduced the span of the present structure to 554.5 ft.

In August, 1902, the writer made surveys of the site of the old bridge, under the direction of Benjamin W. Guppy, M. Am. Soc. C. E., Bridge Engineer of the Maine Central Railroad. The designs of the new bridge, both substructure and superstructure, were developed by Mr. Guppy and approved by Mr. T. L. Dunn, Chief Engineer, the following winter.

On March 14th, 1902, application was made to the Secretary of War for permission:

"To substitute a steel plate-girder bridge on stone piers for the wooden trestle bridge on wood cribs and piles, built 1892 to 1896, which replaced the wooden bridge originally constructed about 1872."

The contract for the substructure was awarded to Ellis and Buswell, of Woburn, Mass., and the writer was assigned as Resident Engineer in Charge.

Work was begun on May 19th, and completed on December 10th, 1903.

The design called for six piers and two abutments of first-class ashlar granite masonry, with foundations of piles and concrete, as shown on Fig. 1, the general drawing, which also shows the old wooden bridge.

As will be seen by this drawing, the plan was to construct the new masonry without interfering with the passage of trains. The specifications also called for the construction of Pier No. 4 last, in order that the channel might be blocked and navigation impeded for the shortest time possible.

Abutments.—Work on the west abutment was begun first. One trestle bent of the old bridge came directly on the abutment site, as shown on the general drawing. Its removal was effected by driving a bent of six piles just east of the front line of the foundation, and a bent of six piles west of the rear line of the foundation. The track was then supported by three 8 x 14-in. track sticks under each rail, with a clear span of 21 ft. The regular stringers were blocked up on the new bents, and the interfering ones removed.

The excavation was carried to Elevation 43, or 1 ft. above low water. (All elevations are from an arbitrary datum.) The original

FIG. 1.—EAST ABUTMENT, MARSH RIVER BRIDGE.

FIG. 2.—THE OLD MARSH RIVER BRIDGE, LOOKING EAST.

plan was to drive piles here, as in all the other foundations. Hydraulic borings had been made in various localities, and the results are shown on the general drawing. When the excavation reached Elevation 43, a very firm, hard clay was encountered. So promising did it seem for a good foundation in itself that it was tested for bearing power. A 12 x 12-in. timber was arranged with a free vertical motion and loaded with a weight of 9 860 lbs., with no settlement. As this was largely in excess of the unit load the finished foundation was to bear, it was deemed safe to build without the piles, which was done. The east abutment was a duplicate of the western one, with the exception that the foundation piles were driven as shown.

One bent of the old bridge was directly on the east abutment site, and the first bent east was in danger of being undermined by the excavation. A bent of six piles was driven in front of the abutment site and a bent of four piles east of the threatened bent. The track was carried on three 8 x 14-in. sticks under each rail. The two trestle bents were removed and a third bent of four piles was driven to replace the easterly or threatened bent, narrowing the clear span to 20.3 ft.

On the west abutment, the excavated material deposited in front was sufficient to keep out the water. Lower ground adjoining the east abutment made some sort of a coffer-dam necessary. This was built with the clay excavated, faced and capped with turfs of marsh grass. After the collapse of a small section, at the start, a dam of sufficient height and strength was easily and quickly built. Beyond being overflowed by an extra high run of tides in August, this dam served its purpose admirably, with a minimum amount of leakage. A ditch pump handled all the water in the west abutment. A 6-in. centrifugal pump was used at the east abutment to clear the pit when necessary, but a smaller pump would have answered as well.

The abutments were laid with a boom derrick erected on the fill near the ends of the bridge. The general character of the masonry, and the method of carrying the track are shown in Fig. 1, Plate I.

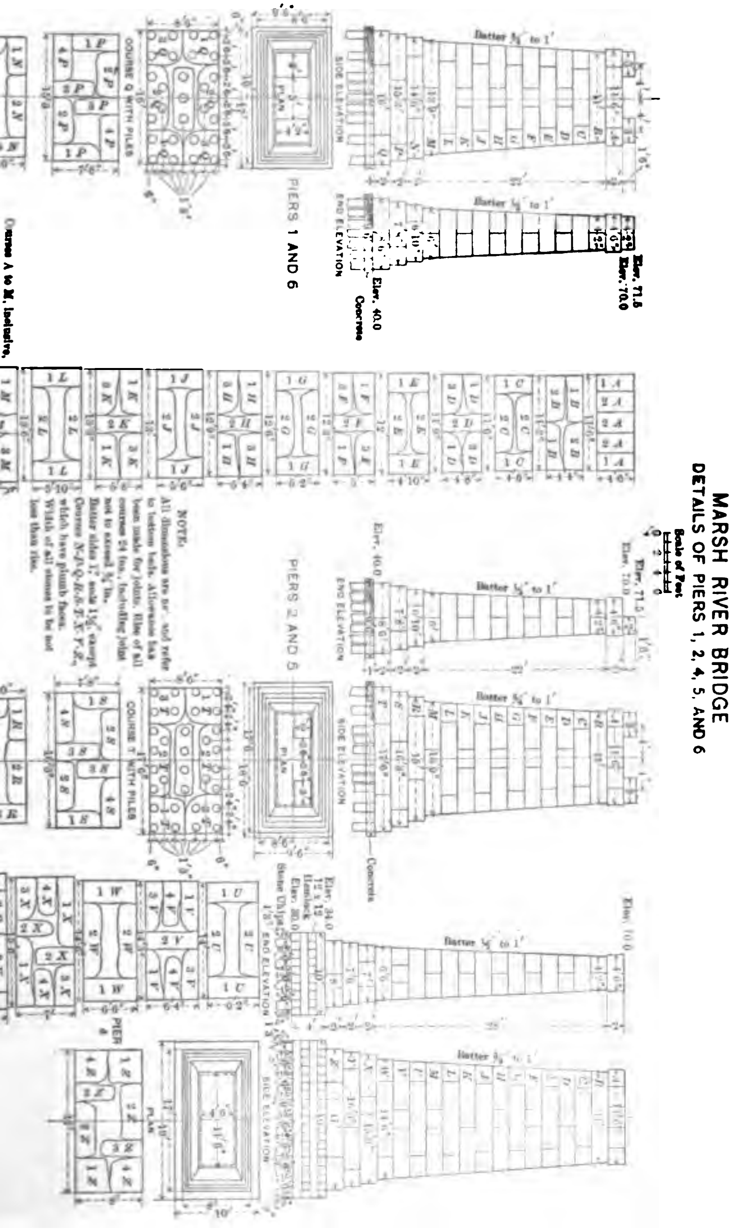
Piers.—Six piers were contemplated, in four of which, *i. e.*, Piers 1, 2, 5 and 6, the piles were cut off at Elevation 40, or 2 ft. below low water. The construction of these piers will be described first. The piles in Piers 3 and 4 were cut off at Elevation 30. Their construction will be taken up separately.

For Piers 1, 5 and 6, no track preparation was necessary
Pier 2, the first bents, both to the east and west, were remove
the crib shown on the east side was cut down close to the midd
of the group of three bents shown on the plan. A bent of fou
was driven west of the group of two, and the track was carried
12 x 12-in. track sticks under each rail, with a span of 15.3 ft.

The sites of Piers 1, 2, 5 and 6 were directly over the old cr
of the original bridge. The material to be excavated consisted
cribwork, filled with rocks and mud from the flats. The nature
material is indicated in Fig. 2, Plate I, a view of the old bridge l
east from the channel. This excavation was the hardest an
tedious part of these four piers. It was only possible to work
tide or low tide. The old cribwork was so sound that it was ne
to cut nearly every timber, it being impossible to start them w
car derrick. Piers 1, 2 and 6 were excavated and the pits cribbe
2-in. plank. Pier 5 was in deeper water on the north side, and
necessary to drive a coffer-dam of 3-in. grooved and splined t
Small boulders under the dam were removed by grappling for th
means of iron rods with hooks on the ends. After loosenin
they were brought to the surface by workmen diving for the
water being about 5½ ft. deep. This was a crude method, but,
to the small quantity of rock to be moved, it was quite effective

The excavated logs and rocks were used to build temporar
work, normal to the bridge, to carry the rear of the pile-driver
driver was supported beneath the bridge on a platform of 12 x
timbers built on the adjacent bents of the old bridge. The
was mounted on 10-in. hollow iron rolls running under a g
carriage. Motion sideways was secured by sliding the carri
the rolls by a rope rove from the carriage to the old bridge and
drum of the engine.

The longest pile that could be put in the driver was about 3
When longer ones were necessary, they were driven from the
by the derrick car. For this purpose, leads, 26 ft. long, w
a top or bottom, were made. The piles were placed in p
through openings in the ties. The leads were then raised by th
runner and placed on the pile, the whole being held in pl
watch-tackles. The hammer was then put into the top of the
and manipulated by the regular fall of the car's hoisting e


MARSH RIVER BRIDGE
DETAILS OF PIERS 1, 2, 4, 5, AND 6
PIERS 1 AND 6
PIERS 2 AND 5
NOTE.
SIDE ELEVATION
END ELEVATION
PLAN
Concrete

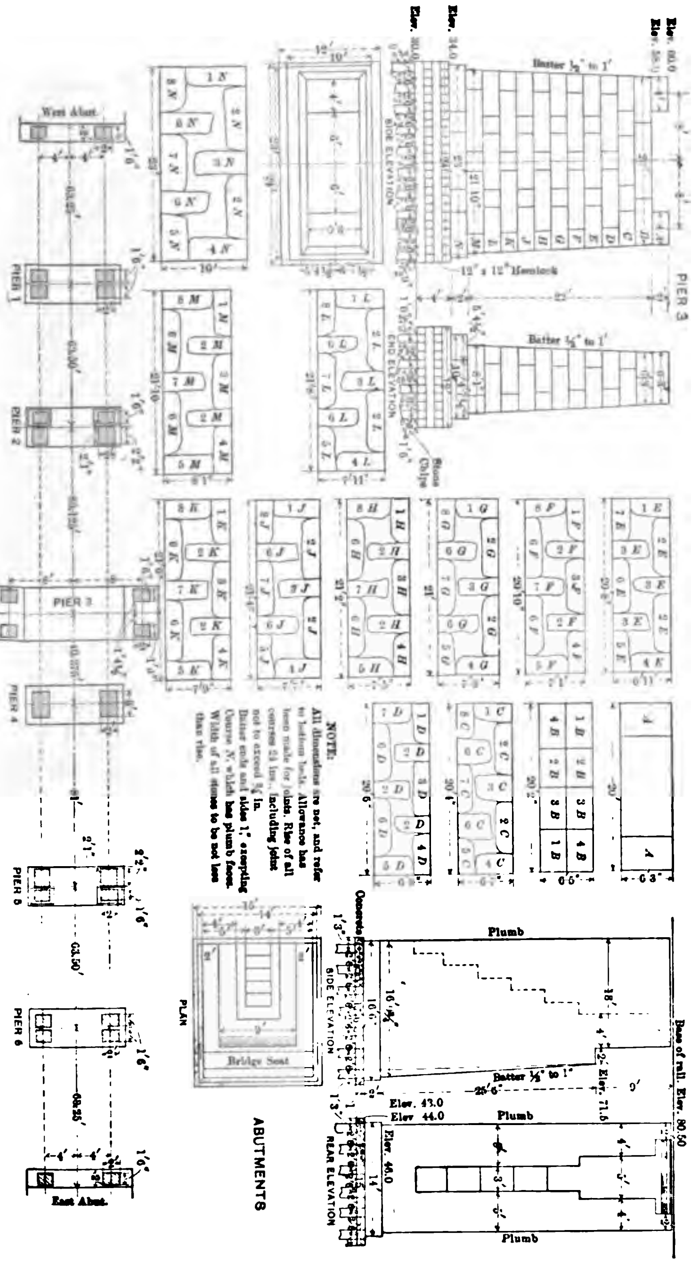
When the piles had been driven to such an elevation that the driver mounted below could be rolled over them, the hanging leads were removed and the piles followed home from below. A view of this is shown in Fig. 1, Plate II, which also shows Pier 1, and the old cribs, etc., at low water.

After the piles were driven, the pits were pumped out by a 6-in. centrifugal pump, the piles were cut off and the concrete laid. The masonry was laid, with a self-propelling car derrick, from the track. All stones for the piers came to the work cut and ready to lower into place, as shown by the detailed plans. On these piers the cribs and coffer-dams were carried only to about Elevation 44; there being no attempt to work on the masonry except at low water.

Piers 3 and 4.—To carry the track during the construction of Pier 3, a bent of six piles was driven west of the proposed pier, and a trestle bent erected on a projection of the west side of the old draw pier. The bents which are shown on the general drawing as interfering with the construction were removed, the track being carried on three 8 x 14-in. sticks under each rail, in addition to the regular beams, the clear span being 17.1 ft.

The excavation for Piers 3 and 4 was largely old rip-rap with some flats mud. It was removed by an orange-peel dredge bucket hung to a boom attached to the adjacent bents of the old bridge. The material was discharged on a scow which was run beneath the bucket. It was only possible to work from low to half tide, lack of head room not permitting the bucket to be raised high to deposit on the scow at high water. The engine was mounted on a platform on the old cribbing.

In excavating for Pier 3, considerable old cribwork was encountered. For its removal, the power chisel, shown in detail in Fig. 4, was constructed. This chisel was bolted to a pile butt, and after being placed over a timber to be removed, was driven through it in a manner similar to that described for driving long piles. Some of the timbers thus detached were too water-soaked to come to the surface. They were raised by a pair of large timber hooks, made of $\frac{5}{8}$ x 3-in. iron, secured to the ends of handles, 15 ft. long, and manipulated from the scow. After a successful hitch had been made with this set of mammoth pinchers, the timbers were lifted by the car derrick. Both the hooks and the chisel are shown in Fig. 2, Plate II.


PIER 3
Batter ½" to 1'
12" x 12" Hemlock
SIDE ELEVATION
END ELEVATION
West Abut.
PIER 1
PIER 2
PIER 3
PIER 4
PIER 5
PIER 6
East Abut.
NOTE:
All dimensions are net, and refer to bottom beds. Allowance has been made for joints. Rise of all courses 24 ins. including joint not to exceed ⅜ in.
Batter ends and sides 1" excepting Course N, which has plumb faces.
Width of all stones to be not less than rise.
Plumb
Base of rail. Elev. 80.50
Bridge Seat
PLAN
SIDE ELEVATION
REAR ELEVATION
ABUTMENTS

An improvement on the chisel could have been made by giving the blade a greater length than 14 ins., and a little greater depth than 4½ ins., thus making it easier to place it on a sunken timber.

The piles in Pier 3 were driven from a platform supported by the bents of the old bridge. Here it was necessary to use two followers. A follower 10 ft. long was used first to drive the pile to a point where a 25-ft. follower could be used to drive the pile home; this being necessary because the hammer could be dropped only 19 ft. without leaving the bottom of the leads. The piles in Pier 4 were driven from a scow in the usual way.

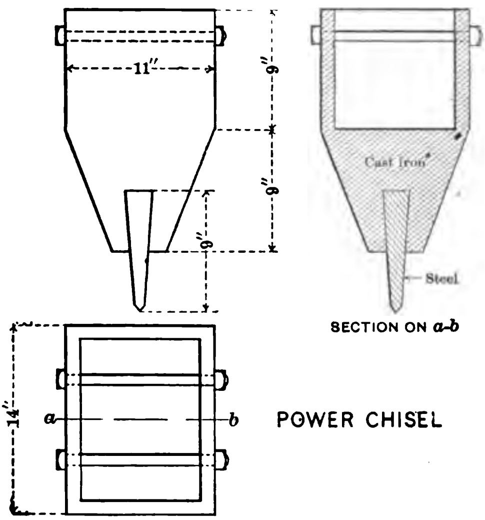


FIG. 4.

The piles shown on the general drawing are to scale, as to the depths driven, and thus show the approach of actual driving to the borings made by the hydraulic process.

Cutting the piles off at Elevation 30, 12 ft. below low water, gave more trouble and caused more expense and delay than any other part of the work, especially in Pier 3. In Pier 4, they were cut off with a 34-in. horizontal circular saw mounted on a 4-in. shaft, 27 ft. long. The shaft was attached to an upright 12 x 12-in. timber with three bearings 6 ft. apart. The stick was fastened in the leads of the pile-driver mounted on a scow. The shaft was suspended by a tackle

FIG. 1.—DRIVING LONG PILES, MARSH RIVER BRIDGE.

FIG. 2.—TIMBER GRAPPLES AND POWER CHISEL, USED AT MARSH RIVER BRIDGE.

with a swivel which admitted of its rotation and vertical adjustment through its bearings. The power was transmitted to the shaft by a 6-in. belt from the pile-driving engine. The saw was set in position by a submarine diver, and kept at the correct elevation by aligning the shaft with a wye-level. The saw was fed against the shaft by shifting the scow with bow and stern lines and watch-tackles. The extreme swiftness of the tide made it impracticable to work except from low to half tide. Much trouble was caused by getting the saw into two piles at once, which caused binding. This happened once during a rapidly rising tide, and resulted in a bent shaft. Trouble was caused, also, by continual slipping of the belt. On the whole, the efficiency of the outfit was very disappointing. The thirty-two piles were cut off in six days, including all delays for tide, etc., and two days lost by the bent shaft. The diver reported a very creditable result at the finish. For cutting off the piles in Pier 3, the same outfit was tried. The leads and engine, in this case, were mounted on rolls, as in the pile-driving. The bearing boxes were changed to 10 ft. apart, and a 10-in. belt was substituted for the 6-in. belt. It was also necessary to remove the side braces from the leads to permit work to be done close to the old bridge. When the engine was started, the vibration of the platform was so great that the leads and engine traveled sideways on the rolls, and even the rolls shifted. The result was that the saw, on being fed into a pile, had a swaying motion which jammed the teeth hard into the wood, and stopped the saw with a sharp jerk. After a series of attempts to remedy the trouble, the saw was abandoned. The principal difficulty in the use of the horizontal saw seemed to be due to four causes: First, in feeding the saw gradually into a pile which was entirely invisible; second, the extreme swiftness of the tide; third, the continued tendency of the belt to slip; fourth, lack of engine power (an 8 x 12-in. single-cylinder engine was used).

On abandoning the power saw in Pier 3, the piles were cut by two submarine divers, the cut-off being given them on each pile by a 28-ft. iron pipe, 1¼ ins. in diameter, and a wye-level. The forty piles were cut off in seven days, on four days of which only one diver worked. The divers worked from three to four hours daily. Their principal trouble seemed to be in getting a proper saw. Several kinds were tried, but none seemed to be entirely suitable for the work.

After the piles were cut off, stone chips were dumped among the pile heads and leveled by the divers. These chips were rated as concrete.

The method first proposed for the construction of Piers 3 and 4 was by a floating caisson, the bottom of which was to be the grillage of 12-in. timbers shown on the detailed plans, the sides to be removable. The writer suggested as a substitute the device which was finally used. For Pier 4 a bent of four piles was driven on each side of the site of the pier and cut off at Elevation 45.17, as shown in Fig. 5. These piles were capped with 12 x 12-in. hard pine. Three stringers

DEVICE FOR CONSTRUCTING PIER 4. MARSH RIVER BRIDGE. SOUTH NEWCASTLE. ME.

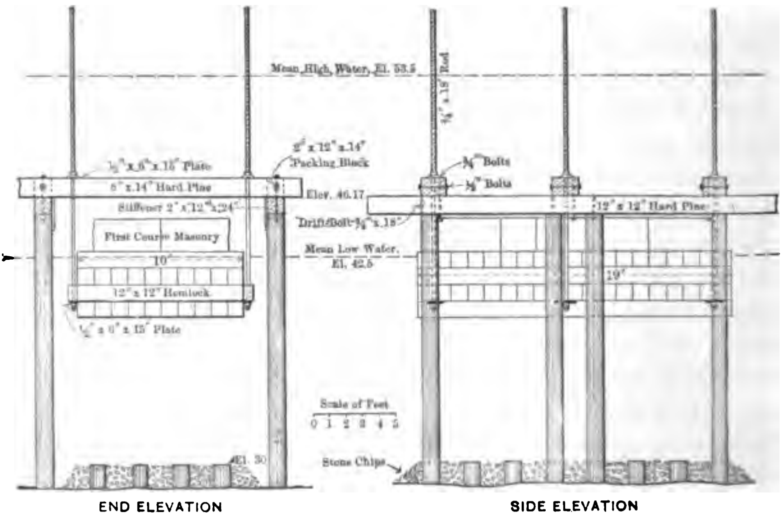


FIG. 5.

of two 8 x 14-in. hard pine, spaced 2 ins. apart, were set at such points as to be directly over the lowering rods when the grillage should be over its proper position on the piles. The two end and center sticks of the next to the bottom course of the 12-in. timbers in the grillage were given a projection of 6 ins. on each side; each timber being cut out 1 in., thus making a 2-in. slot 6 ins. deep. The lowering rods, six in number, were of $1\frac{3}{8}$-in. iron, 10 ft. at the top being threaded. The grillage was floated into position beneath the stringers on a falling tide, and the rods were inserted in the slots and plumbed. Two nuts

and a ½ x 6 x 15-in. plate washer were used on the bottom of each rod, and a washer of the same size, with the addition of a 9-in. round washer and one nut, was set on top of the stringers. After placing in position, a course of stone was laid and the upper nuts slacked as much as possible before the rising tide flooded the work. Wedges were placed between the top of the masonry and the stringers as a preventive of possible lateral motion. This operation was repeated at each tide, and on the seventh tide the grillage rested on the piles, and was practically correct as to both level and position. Darkness prevented utilizing the whole of each tide, or the pier would have been lowered in five tides, *i. e.*, one course to a tide.

After the grillage rested on the piles, the stringers, rods, etc., were removed and used again in Pier 3 (which, contrary to expectation, was built after and not before Pier 4). The remainder of Pier 4 was built up to high water as tide work.

Pier 3 was constructed by the same means as Pier 4. Here, however, one nut was left off the bottom of each rod, and the rods were headed up. Two polished steel washers were also inserted between the lowering nut and the 9-in. cast washer. An improvement on this device could be made by inserting a ball-bearing washer below the lowering nut. Also, the use of three connected ratchet wrenches on each side would have assured an equal turning of all nuts, and obviated an occasional binding. Pier 3 was landed on the piles in ten tides, and then completed rapidly.

The pier masonry and excavation, throughout, was carried on with a self-propelling derrick-car working under flag protection. This car was the property of the contractors, Ellis and Buswell, and on this work, especially, was a valuable piece of machinery, as it enabled them to bring out stock to any pier, and work directly over it. From the beginning of the work until the middle of October there were thirteen trains during working hours, and after that time, seven trains. Waiting for trains caused some delay, especially at low tide.

Table No. 1 is a force account, in connection with which a word of explanation is due. The small amount under "Laborers," in proportion to men of higher wages, is due to the fact that the masons, blacksmiths, etc., worked on excavations, pile-driving and other work, as time or tide made necessary, it being impossible to work a large crew to advantage.

TABLE No. 1.—Force Account.

	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.
Foreman	11	25	26	28	27	28	28	9	182
Stone cutters	......	......	......	24	32	......	......	......	56
Masons	30	90	109	101	78	56	69	27	560
Engine runners	11	41	38	81	64	52	28	9	324
Blacksmith	11	25	25	28	26	28	28	9	180
Derrick men	11	41	28	28	26	28	25	9	196
Mortar men	......	17	25	28	26	9	15	9	129
Laborers	27	64	50	78	79	72	90	26	486
Divers	......	......	......	......	......	3	20	4	27
Diver's tender	......	......	......	......	......	3	20	4	27
Flag	......	20	25	25	26	27	25	9	157
Totals	101	323	326	421	384	306	348	115	2 324

All cement used on the work was subjected to the accelerated tests recommended in the report of the Special Committee on Uniform Tests of Cement.* The water of the river, which was used on the work, was also used in the tests.

The final estimate of work done is given in Table No. 2.

TABLE No. 2.—Final Estimate.

Excavation of earth and old cribs	1 397 cu. yds.
Piles, below cut-off	8 068 lin. ft.
Concrete and chips in Piers 3 and 4	84 cu. yds.
Timber in grillage in Piers 3 and 4	22 944 ft., B. M.
Pier masonry	579 cu. yds.
Abutment masonry	463 cu. yds.

The filling about the two new abutments was deposited by the railroad company, and consisted of limestone chips from the quarries at Rockland, 33 miles distant.

The writer regrets that he is unable to show any photographs of the method of lowering the masonry of Piers 3 and 4, as an accident in the darkroom caused all the negatives to be light struck.

The nuts were turned by key wrenches with handles about 4 ft. long. In both piers, five courses were in place before they rested finally on the pile heads. Most of the time, it required two men on each wrench. With the improvements mentioned, and where the current was less rapid, this method would be most successful; even

* *Proceedings*, Am. Soc. C. E., January, 1903.

in this work, with the current and heavy load, the lowering was done without a hitch.

A question as to the probability of sea worms attacking the timber grillage has been asked. The timber cribs and piles of the old bridge, on examination, do not show a single instance of any attack of this nature, and there seem to be no reason for anticipating any.

The swiftness of the tide has been mentioned. By an examination of the general plan it will be seen that the cribs of the old bridge contracted the river to a large extent.

There were no means at hand to determine the actual current velocity, but it was swift enough to make all water work exceedingly difficult.

Vol. XXX. FEBRUARY, 1904. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE LOCATION OF THE KNOXVILLE, LA FOLLETTE AND JELLICO RAILROAD, OF THE LOUISVILLE AND NASHVILLE SYSTEM.

By W. D. Taylor, M. Am. Soc. C. E.

To be Presented March 16th, 1904.

There are experienced field engineers to whom the perusal of this paper will be a loss of time. Many engineering papers deal with the special characteristics of special structures, to the exclusion of broader questions. The experienced engineer spends most of his time in thinking out the details of such structures, and, when he writes an account of his work, assumes that his readers will grasp at once the broader questions involved, and will be interested only in the special designs which have taxed his own ingenuity most. This would be all very well if his writing fell only under the eyes of experienced readers; but, probably, ten inexperienced readers, ten students, perhaps in search of information, will read his article carefully where one busy and experienced engineer gives it hasty perusal. For the inexperienced reader, the broad questions affecting the whole

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

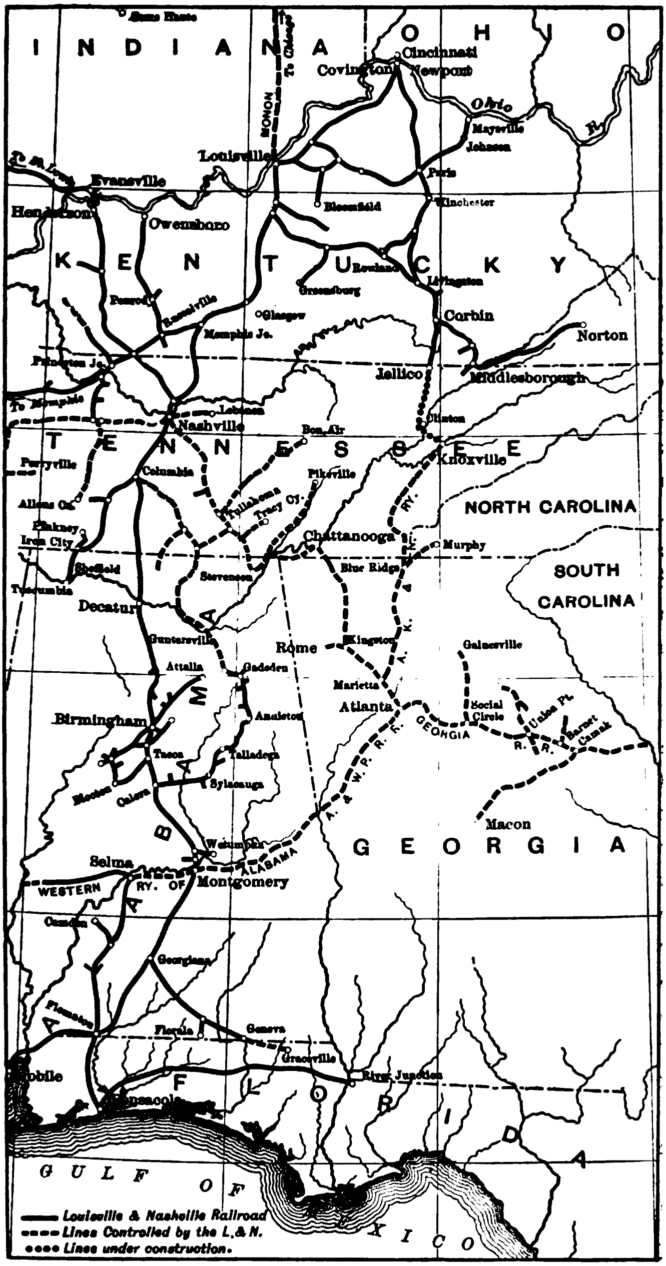

INDIANA
OHIO
Cincinnati
Covington
Newport
Ohio
Maysville
Johnson
Louisville
Evansville
Henderson
Owensboro
Paris
Bloomfield
Winchester
KENTUCKY
Greensburg
Livingston
Corbin
Norton
Memphis Jc.
Princeton Jc.
Jellico
Middlesborough
Nashville
Lebanon
Clinton
Bon Air
TENNESSEE
Knoxville
Perryville
Columbia
Pikeville
Tracy Cy.
NORTH CAROLINA
Chattanooga
Murphy
Iron City
Sheffield
Stevenson
Blue Ridge
SOUTH CAROLINA
Tuscumbia
Decatur
Guntersville
Rome
Kingston
Gainesville
Attalla
Gadsden
Marietta
Atlanta
Social Circle
Birmingham
Anniston
GEORGIA R. R.
Talladega
Sylacauga
Macon
GEORGIA
Selma
Montgomery
WESTERN RY. OF ALABAMA
Camden
Georgiana
Flomaton
Florala
Geneva
Graceville
Mobile
Pensacola
River Junction
FLORIDA
GULF OF MEXICO
Louisville & Nashville Railroad
Lines Controlled by the L. & N.
Lines under construction.

Fig. 1.

proposition are oftentimes of more value than a minute description of the details of special structures. For him a discussion of the economic questions which determined that the whole project of construction was advisable may be of more importance than the most intricate and learned calculation upon the strength or efficiency of special structural parts; or, to be still more specific, the reasons for building a road in one valley rather than in another offering a shorter route may be more instructive to the majority of readers than any or all of the detailed masonry plans worked out in the construction of the road. In this paper the writer has attempted to set forth the considerations which determined each important step in the lay-out of what he believes is the most important engineering work undertaken in recent years in the section of country in which this road lies. The paper does not even mention the part of the work on which the writer spent most of his force; but, in his judgment, it includes an account of all the best work accomplished on this undertaking, both by himself and by those working over and under him.

In March, 1902, the writer was tendered the position of engineer of construction of the Knoxville, La Follette and Jellico Railroad, with the assurance that the line was to be constructed "through difficult country."

The Louisville and Nashville Railroad Company has a line from Cincinnati to Jellico and from Louisville to Jellico (see Fig. 1). At this time, the company had just acquired control of the Atlanta, Knoxville and Northern Railroad. For some years previous, it had operated the Georgia Railroad under a joint lease with another company. For a long while, it had had a large, if not a controlling, interest in the Atlanta and West Point Railroad and in the Western Railway of Alabama. Thus the system was in entire or partial control of some 900 miles of road to the south of Knoxville, with which it had direct connection only at Montgomery, and connection through a controlled road at Atlanta. From Fig. 1 it will be seen that, in order to have these properties closely united to the body of the system, as well as to operate through trains from Cincinnati and Louisville through Knoxville to Atlanta, the construction of the gap from Jellico to Knoxville was necessary.

The order for the survey and construction of the line was not accompanied by any of the usual tentative conditions. A fair traffic

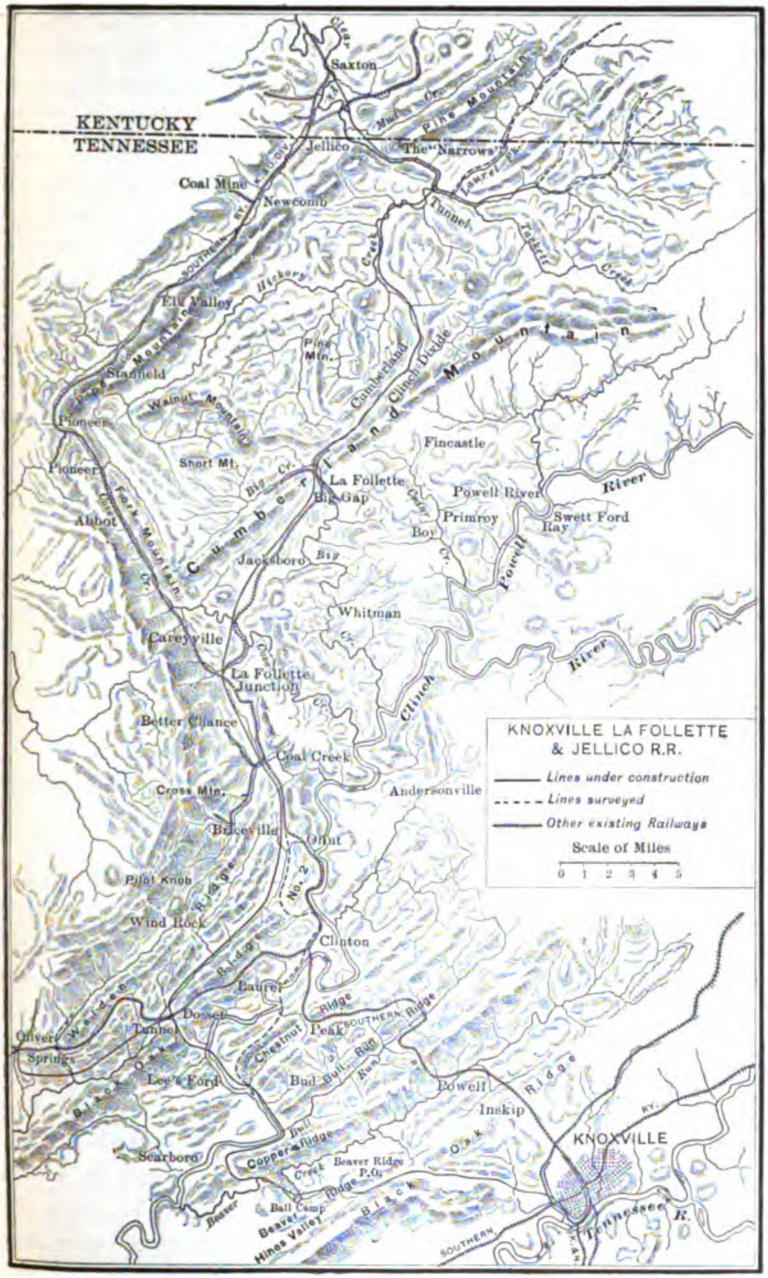

KENTUCKY
TENNESSEE
Saxton
Jellico
The "Narrows"
Pine Mountain
Coal Mine
Newcomb
Tunnel
Laurel
Elk Valley
Hickory
Creek
Pine Mtn.
Stanfield
Walnut Mountain
Pioneer
Short Mt.
Cumberland Mountain
Cumberland
Clinch Divide
Fincastle
La Follette
Big Gap
Big Cr.
Powell River
River
Primroy
Swett Ford
Ray
Boy
Abbot
Fork Mountain
Jacksboro
Powell
Whitman
Careyville
La Follette Junction
Clinch
River
Better Chance
Coal Creek
Cross Mtn.
Andersonville
Briceville
Offut
No. 2
Pilot Knob
Wind Rock
Ridge
Clinton
Laurel
Dossett
Tunnel
Olivers
Springs
Walden
Peak
Chestnut
Ridge
SOUTHERN
Lee's Ford
Bud
Bull Run
Powell
Inskip
Black Oak
Ridge
KNOXVILLE
Scarboro
Copper Ridge
Bull
Beaver Ridge P.O.
Creek
Ball Camp
Beaver
Hines Valley
Ridge
Tennessee R.
SOUTHERN
KNOXVILLE LA FOLLETTE & JELLICO R.R.
Lines under construction
Lines surveyed
Other existing Railways
Scale of Miles
0 1 2 3 4 5

FIG. 2.

could be safely counted on for the new line, from the day of its completion, without considering the large local traffic which could probably be developed along the route. Thus the chief executive of the road was warranted in authorizing expensive construction, if need be, to secure good grades and alignment.

The distance from Saxton, Kentucky, to Knoxville, Tennessee (see Fig. 2), on a straight line, is approximately 51 miles; *via* the Louisville and Nashville to Jellico, and the Knoxville and Ohio Branch of the Southern from Jellico to Knoxville, it is 68.3 miles. This branch of the Southern was built years ago, when, in the location of railways, little attention was paid to future economy in operation. The line, in places, has grades of 93 ft. to the mile, uncompensated over stiff curves, even near the tops of long ascents. Helper engines are used freely on the line, even on passenger trains. But the traffic in south-bound bituminous coal, from Jellico, Pioneer, La Follette, Coal Creek, Briceville and Oliver Springs, is large enough, it is said, to make this one of the best paying lines of that system.

The entire country between Saxton and Knoxville has been covered by the United States Geological Survey, and the maps of this Survey, though found to be very inaccurate as regards topography in country inaccessible by horse or wagon, was of untold value in choosing the routes for the line.

Waldens Ridge and Cumberland Mountain (See Fig. 2) divide the district into two parts, unlike in geography, topography, and geology. That portion of the country to the northwest of this ridge and mountain is part of the Cumberland plateau of the Appalachian province. The drainage, for the most part, is to the north and northwest into the Cumberland River. The portion of the district to the southeast of this divide is a part of the great valley of East Tennessee, and the general drainage is to the southwest into the Clinch and Tennessee Rivers. To the northwest of this dividing line, the surface rocks are Carboniferous; to the southeast they are Cambrian and Silurian. The country to the northwest of this line is so broken and rugged that it may be called the mountain district. Here the divides rise to elevations of from 2 500 to 3 600 ft., large areas being above 3 000 ft. The streams fall rapidly, from their sources, and emerge into the valleys at elevations of from 800 to 1 100 ft. These valleys are deep and narrow, and the slopes rise brokenly. The crests of the mountains

are narrow and flat, many of them being susceptible of cultivation; but, so far, the steep and rugged slopes have proved to be effectual barriers to the settlement of the district, except by the scattered cabins of mountaineers. There are homes in these mountains which have been occupied for generations, with no wheeled vehicle ever in use until roads were opened by the contractors for the construction of this railroad. The mountain ranges are cut in two by occasional streams, and thus all possible routes on reasonable gradients are well defined.

In the valley district, erosion has produced a series of long ridges separated by long, parallel and narrow valleys which follow closely the belts of rock. Their general direction is northeast and southwest, thus crossing the direction of the line of survey, which lay somewhat northwest and southeast. The surfaces of these small valleys are at elevations of from 800 to 1 100 ft., and the parallel ridges rise from 100 to 500 ft. above them. Some few of these ridges are cut in two by streams, but most of them are continuous for many miles. Copper Ridge, on the south side of the Clinch, which ridge is responsible for the second large détour to the westward in the line of road between Coal Creek and Knoxville, was such a continuous ridge. From the point where the road cuts through it, for 30 miles to the northeast, there is not a gap in which the crest is not more than 350 ft. above Bull Run Valley on the north side of it. The conditions as to continuity were somewhat similar in the case of the two Black Oak Ridges. Thus the problem of getting the best location was a more difficult one in the less rugged country.

Clear Fork River cuts through Pine Mountain in a gorge called "The Narrows," so rugged that no domestic animal had ever traversed it. It lay across the straight line joining Saxton and Knoxville. The stream, Big Creek, cuts through Cumberland Mountain at Big Creek Gap, which lies some 24 miles from Saxton and about 4 miles west of the direct route. Further, a branch line of road had been constructed through this gap (see Fig. 2), and to a connection with the Southern Railway near Careyville. At the gap, the mining town of La Follette, with limestone and sandstone quarries, coal and iron mines, coke ovens, a furnace, etc., had sprung up and in three years had grown from a village of less than 500 to a population of more than 6 000. Thus these two water gaps were objective points. In fact, the route through these points had often been explored, and at least two

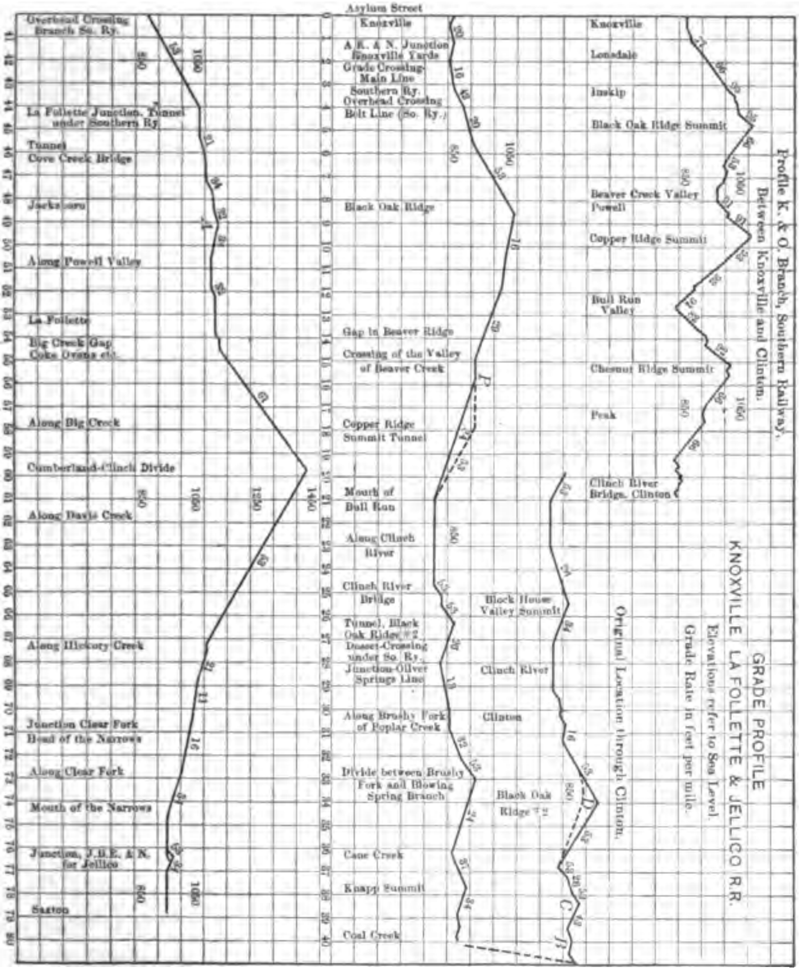
careful surveys had been made on it during the twenty years or
that the Louisville and Nashville Railroad had had under conte
tion the extension of their Knoxville Division to the city for whi
division was named. As there were watercourses leading from e
these points toward the other, the choice of the route joining the
simply in deciding which slope of the narrow valleys offered th
support for the adopted gradient. But these valleys were so to
and narrow that in a distance of 3 miles on one of them it was
sary, even when using 10° curves with 300-ft. minimum tange
bridge the watercourse ten times and use three short tunnels.

It was plain, from the conformation of the country, that
would be long ascents and descents on whatever ruling grad
adopted. The chief local product of the country being bitum
coal, in great quantity and of good quality, the market for which
only be southward, since the country to the north and wes
tributary to the Pittsburg coal fields and that to the east to th
ginia coal fields, it was good economy to spend more money to
light grades against south-bound trains than for trains in the op
direction.

The writer decided on 53-ft. compensated grades as the max
but an economical construction required the introduction of a
grade on the long descent from the Cumberland-Clinch divide
Follette. The road was located from Saxton to this divide o
ruling grade, with an inconsiderable amount of adverse gr
miles from Saxton, at a point where its introduction was compar
harmless.

An adverse grade has been defined as a grade pitching
opposite direction from the general slope of the country. Of c
it means the introduction of just so much rise and fall which co
avoided.

The line from La Follette to Knoxville had not been reconno
It seemed possible to get a line from the Cumberland-Clinch
down to the Clinch without adverse grade; but from the Cli
Knoxville, across the short ridges and valleys, it seemed that th
would have to "rise and fall with the country," and the wri
pected at the outset that the condensed profile of this part of t
would look like the teeth of a saw. From La Follette toward
ville, the narrow and tortuous valley of Big Creek seemed to of



GRADE PROFILE
KNOXVILLE LA FOLLETTE & JELLICO R.R.
Elevations refer to Sea Level.
Grade Rate in feet per mile.
Profile K. & O. Branch, Southern Railway,
Between Knoxville and Clinton.
Original Location through Clinton.
Overhead Crossing Branch So. Ry.
La Follette Junction, Tunnel under Southern Ry.
Tunnel
Cove Creek Bridge
Jacksboro
Along Powell Valley
La Follette
Big Creek Gap, Coke Ovens etc.
Along Big Creek
Cumberland-Clinch Divide
Along Davis Creek
Along Hickory Creek
Junction Clear Fork
Head of the Narrows
Along Clear Fork
Mouth of the Narrows
Junction, J.B.E. & N. for Jellico
Saxton
Asylum Street
Knoxville
A.K. & N. Junction Knoxville Yards
Grade Crossing Main Line
Southern Ry. Overhead Crossing
Belt Line (So. Ry.)
Black Oak Ridge
Gap in Beaver Ridge
Crossing of the Valley of Beaver Creek
Copper Ridge Summit Tunnel
Mouth of Bull Run
Along Clinch River
Clinch River Bridge
Tunnel, Black Oak Ridge #2
Dossett-Crossing under So. Ry.
Junction-Oliver Springs Line
Along Brushy Fork of Poplar Creek
Divide between Brushy Fork and Blowing Spring Branch
Cane Creek
Knapp Summit
Coal Creek
Block House Valley Summit
Clinch River
Clinton
Black Oak Ridge #2
Knoxville
Lonsdale
Inskip
Black Oak Ridge Summit
Beaver Creek Valley
Powell
Copper Ridge Summit
Bull Run Valley
Chesnut Ridge Summit
Peak
Clinch River Bridge, Clinton

Fig. 3

most available route in the desired direction; but to get from the Clinch, at the mouth of Big Creek, across to Knoxville on 1% grades was out of the question, unless one made up his mind to make long tunnels through nearly all the ridges and to make high crossings over the narrow valleys. The difficulties and expense were so great that this route was never comtemplated seriously.

By going down Big Creek from La Follette to the Clinch, however, and then turning down the Clinch as far as the mouth of Bull Run, below Clinton, and by making three crossings of the Clinch, a route was possible, leading through Clinton, a town of 1 200 people, which gave no adverse grade from La Follette to Clinton and an adverse grade of only 48 ft., vertical, between Clinton and Bull Run, at a point about 4 miles southwest of Clinton where it was necessary to cut across country, leaving the river, to save distance and excessive curvature.

The absence of adverse grade was considered so advantageous on this route that a careful survey was made over all the difficult portions of it, and careful estimates were made of the value of its advantage and cost as compared with the route adopted finally; but the absence of adverse grade was its sole recommendation. There were many serious objections to it. First, to follow Big Creek Valley below La Follette required bad alignment, several short tunnels and expensive construction; second, the three crossings of the river involved expensive bridging; third, the distance from La Follette to Clinton was greater than by the route adopted finally; and, fourth, it led out and away from the coal fields, and through a country from which the timber had already been stripped and from which little development could be expected.

From La Follette to Clinton the route adopted originally followed very closely the line described previously as dividing the country into dissimilar sections. The route could only be adopted at the sacrifice of introducing a considerable amount of adverse grade at four different places (see Fig. 3 at *A*, *B*, *C*, and *D*). There were 28 ft., vertical, at *A*, 12 at *B*, 40 at *C*, and 132 at *D*. But the line was much cheaper than the Big Creek-Clinton line, afforded much better alignment, and, besides following the edge of the coal fields, passed through the town of Coal Creek, the center of a population of some 5 000 people, where coal mining had been carried on successfully for a quarter of a century.

The location from the mouth of Bull Run to Knoxville introduced more difficult problems than any other part of the line; and the writer believes that the combination of conditions which enabled this line from the Clinch to Knoxville to be laid out, on the original 53-ft. grades, without one foot of adverse grade and without a tunnel or high valley crossing, is unique and unusual in such rough country. The profile of the Southern Railway line from Clinton to Knoxville (see Fig. 3) is a fair representation of the necessary line that goes plunging across these ridges. An old locating engineer, of the Cincinnati Southern, years before, made a location survey from Harriman to Knoxville which passed through the same gap in Copper Ridge as that used by the writer. He used 66-ft. uncompensated grades, and got a wonderful amount of rise and fall into his line between Copper Ridge and Knoxville, about 130 ft. of it being between Copper Ridge summit and Beaver Creek.

At the crossings of the parallel valleys of Bull Run and Beaver Creek by the Southern Railway line, the latter valley is the higher by some 140 ft.; and the writer decided to cut through Copper Ridge, by a tunnel if necessary, at the level of the upper valley, to save all unnecessary rise and fall. It was found on examination that the two valleys, though one was so much higher than the other, had practically the same rate of fall, some 30 ft. in the 7 miles below the Southern Railway crossing, so that the point, P (see Figs. 2 and 3), in the open valley of Beaver Creek, was 140 ft. above the country at the mouth of Bull Run. At the point, P, however, where the stream turned and ran directly toward the only available gap in Copper Ridge, the valley began to descend much more rapidly down to the level of the Clinch. It was just possible, on the original 1% grade (see Plate III), to start the grade at the mouth of Bull Run and make the elevation of the upper valley by the time the summit of the ridge was reached at the gap. A cut, 68 ft. deep, containing 186 000 cu. yds. of clay, chert, and rock excavation, was necessary in cutting through the ridge. Supporting ground on the side of the ridge was found from the ridge summit to the point, P, for a level grade, so the road reached P without any unnecessary rise and fall. A water gap in the desired direction led through Beaver Ridge. This gap drained a portion of the open valley (Hines's) between Beaver Ridge and Black Oak Ridge into Beaver Creek, and the

three parallel valleys thus made a succession of steppes whicl used to support the gradient from the Clinch to the sumn Black Oak Ridge at the lowest available gap. The alignmer excellent, and the country easy from the point, *P*, to the sumı Black Oak Ridge, and from there the road descended in fairl country to Knoxville.

There were, in all, five well-equipped engineer parties be Jellico and Knoxville, and the chiefs of parties were caution use as light grades and curves as they reasonably could times.

Just here, at the risk of reiterating much that has already written, the writer wishes to emphasize the necessity, in making surveys as this:

(1) Of not using at any point any more difficult gradients no stiffer curves than the country actually requires;

(2) Of completing a condensed profile of the whole line as so the surveys are connected throughout;

(3) Of compensating for curvature the prevailing long gra less rate than the maximum; and

(4) Of making a diligent study of the whole country, with a v selecting a route with a minimum of adverse grade.

Some of the locating engineers were sent back over their several times to see if they could not get through with li grades and curves, even though the grades and degree of curve had been less than the maximum, and more than one of them very material reductions in the grades which had been used, a as in the degree of curve, without increasing the cost of the materially.

When the condensed profile was made, after the lines were up, it was shown that there were only three points where it had necessary to use 53-ft. grades against south-bound trains, *viz* ascent to the Cumberland-Clinch divide, 8 miles in length; the s to Black Oak Ridge No. 2, 2¾ miles in length, and the ascent to per Ridge summit, 3 miles in length. Up to the time of the pletion of this condensed profile, none of the higher officers o road had hoped to get any better ruling grades through this co than 1% compensated. When the writer decided tentatively o 1% grades, the consulting engineer of the road said to him

you can make it from La Follette to Knoxville on one-foot grades you will be doing mighty well." No other road crossing these mountains anywhere in this section of country had secured anything like such a favorable gradient as this. Lines crossing these mountains, as far south as Birmingham, where the elevation of the Appalachian province is so much less, such as the Georgia Pacific line of the Southern Railway from Birmingham to Atlanta; and the Central of Georgia, Birmingham to Opelika, built in the Eighties, had used 66-ft. grades.

Except the three long grades mentioned, the heaviest south-bound grade was 0.65%; and the advisability of reducing these three 53-ft. grades to 34-ft. grades was at once suggested. What was the reduction worth and what would it cost?

The Cost of the Change.—It was plainly out of the question to reduce the ascent to the Cumberland-Clinch divide to this gradient. It was too long, and involved construction which was too expensive. If the road was to be operated on the lower grade, it was plain that a helper engine must be used on this grade, and, therefore, the cost of maintaining a helper engine would be a legitimate charge against the change to 34-ft. grades. Assuming that the traffic would be proportioned as below, and that the schedule could be arranged so that one engine crew could do the helper service, the annual cost of this service would be about as follows:

Interest on $14 000, cost of helper engine, at 4%.....	$560
Twelve months' wages of crew, at $312.............	3 744
32 544 engine-miles, at a cost of 17.3 cents per mile, for repairs, fuel, water, stores and roundhousemen	5 630
Cost of 32 544 engine-miles to maintenance of way and structures, at $\left(22\frac{1}{4}\% \text{ of } \frac{\$1.08}{2}\right) = 12$ cents..	3 905
Total annual cost of helper-engine service.........	$13 839

In the foregoing estimate, the cost of engine repairs, fuel, etc., is taken from the report of the Pennsylvania Railroad Company for 1902. It is assumed that the engine does half as much damage to the track as the train, the cost per train-mile being $1.08 and the cost to

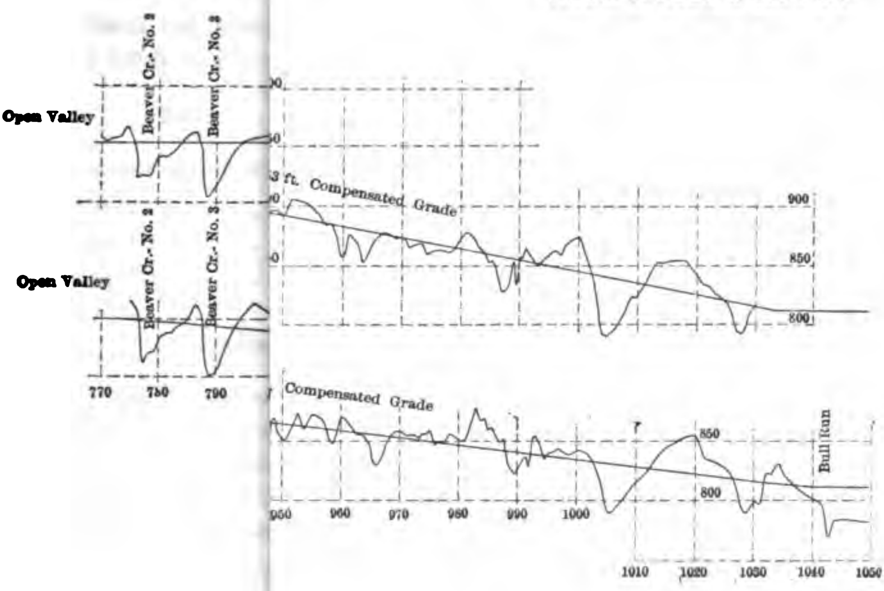
maintenance of way and structures being 22¼% per train-mile. We assume four round trips of 24 miles each per day, from the head of the Narrows to the end of the siding south of the divide, half the trains not running on Sunday.

Then, if the road's capital could be acquired at 4% interest, the cost of establishing and maintaining the helper service would be $345 975.

It was easily ascertained that by making a 700-ft. tunnel at Black Oak Ridge No. 2 the grade there could be reduced to 34 ft. without lengthening the line and without any more expensive construction, except the cost of the 700-ft. tunnel; and, further, the tunnel would save 50 ft., vertical, of the adverse grade.

Plate III is a map and profile of the old and new line at Copper Ridge. By dropping the grade line about 50 ft. at the summit and making a 2 170-ft. tunnel, and by taking advantage of the sharp fall in Beaver Creek Valley from the point, *P*, toward the gap, the 34-ft. grade could be used even here without lengthening the line and without increasing the cost, except by a portion of the cost of the construction of the tunnel. In fact, the lighter grade threw the line off from the upper cliffs of the ridge in certain places down on to the talus slope on smoother ground, with the result that a very much better line, both in alignment and first cost (except for the tunnel), was obtained. In the revision surveys here a maximum curvature of 6° was substituted for 10 degrees. This change had the effect of placing the tunnel of the summit of the ridge on the grade up to Beaver Creek Valley, and there was elevation enough to spare to permit of dropping the grade to 23 ft. per mile through the tunnel, thus compensating for wet rails by more than 0.2 per cent. Thus the cost of the change at these two points was not in excess of the cost of the other line by anything like the full cost of the tunnels. The construction contracts which had been made would warrant the belief that the tunnels could be constructed at a much lower figure, but, inasmuch as these tunnels had to be constructed in part through very treacherous clays, it will be supposed that they would cost $90 per linear foot. Not considering the 50 ft. of adverse grade saved at Black Oak Ridge No. 2, the additional cost of the two tunnels would be about as follows:

PLATE III.
PAPERS. AM. SOC. C. E.
FEBRUARY, 1904.
TAYLOR ON RAILROAD LOCATION.



LLE, LA FOLLETTE AND JELLICO R. R.

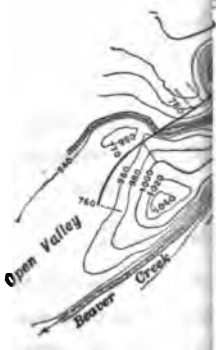
LOCATION THROUGH COOPER RIDGE
FROM
CLINCH RIVER TO BEAVER VALLEY

Scale of Feet

0 1000 2000 3000 4000

Contour intervals 20 feet

otted line in plan is location on 1.00% grade
lid line in plan is location on 0.65% grade



700-ft. tunnel at Black Oak Ridge No. 2, at $90......	$63 000
2 170-ft. tunnel at Copper Ridge, at $90.............	195 300
Total....................................	$258 300

Less cost of summit cut at Copper Ridge:

93 000 cu. yds., earth excavation, at 20 cents.	$18 600	
49 000 cu. yds., chert excavation, at 28 cents.	13 720	
44 000 cu. yds., rock excavation, at 70 cents.	30 800	
		63 120
Additional cost of tunnels.....................		$195 180

The approaches to the tunnel at Black Oak Ridge No. 2 were very nearly as costly as the original summit cut. There was another expense which constituted a legitimate charge against the construction of the tunnels. Up to the time of the contemplated change, the longest tunnel on the road was in the mountain district, in good material, and was less than 900 ft. long. It was certain that the construction of these tunnels would take much longer than the remainder of the road; therefore, the interest on the money invested in construction, including the cost of the valuable property purchased in Knoxville for terminals, from the time that the other work could be completed until the tunnels could be completed, constituted a proper charge against the proposed change. Taking the amount expended in other construction, etc., as $3 500 000, with interest at 4%, and supposing that the tunnels delayed the opening of the road for traffic one year; then the total cost of changing to the lighter grade for south-bound trains would be as follows:

Establishing helper-engine service on the Cumberland-Clinch Divide..................................	$345 975
Additional construction cost of two tunnels..........	195 180
Interest on $3 500 000 for one year at 4%, on account of delay..	140 000
Total cost of change to lower grade............	$681 155

The Value of the Change.—The value of such changes is difficult to estimate with accuracy, even on an operated road on which the traffic is known. It was reasonably certain that the road would not be in operation many years, if operated on 53-ft. grades, before as many as

ten trains per day each way would be required to do its business. Considering the traffic the road would have, probably six of these trains south-bound would be fully loaded. Four fully loaded trains per day, on a 34-ft. ruling grade, could just about do the work of six fully loaded trains per day, on 53-ft. grades, using engines and cars of the same class. Since the north-bound traffic would include a large quota of empty coal cars, and since the same engine that pulled, say, twenty-three loaded 40-ton cars southward against the 34-ft. grades could pull forty-nine empties back against the 53-ft. grades as far as La Follette and forty-four empties back, even against the 61-ft. grade, it was probable that eight trains per day each way on the lesser grade would do the work of ten trains per day each way on the higher grade. Operating expenses vary directly as the train mileage, and the cost per train-mile on the Louisville and Nashville for the year ending June 30th, 1902, is given in "Statistics of Railways" by the Interstate Commerce Commission as $1.08. However, it is a fact that the operation of such heavy trains as these costs more than the general average on a large system. The cost per train-mile on the Duluth and Iron Range and the Duluth, Mesaba and Northern, two roads engaged almost exclusively in traffic similar to that which these omitted trains would represent, is given, by the same authority for the same year, as $1.94 and $2.61, respectively. Probably it would be safe to estimate the train-miles saved at $1.50, but the more conservative figure will be taken. Suppose that half these trains run on Sunday.

Then the annual saving from Saxton to Knoxville would be $1.08 x 4 x 79 x 339 = $116 000, nearly, and the value of this annual saving in operation, with interest at 4%, would be	$2 900 000
The cost of the change, as above	681 155
The amount gained by the change	$2 218 845

However, since helper-engine service could be established and maintained also at Black Oak and Copper Ridges, at a probable cost of $227 000 at each place, the engine mileage at either point not being more than half of that at the Cumberland-Clinch divide, the utmost amount it would have been economical to spend on the change at these two points was about $454 000. Thus it was more economical

to build the tunnels by the amount of \$454 000 less \$195 180 + 140 000, or \$118 820. As soon as the President of the Louisville and Nashville Railroad understood the matter fully he authorized the change, without hesitation.

When the order was made to reduce the south-bound grades to 34 ft., there were some long minor grades on which the curvature had not been compensated, so that the total resistance was above that of the new ruling grade. As the construction had barely begun on most of the line, the corrections were inexpensive; but, if the road had already been in operation, the failure to compensate the prevailing minor grades would probably have resulted in the adoption of a higher ruling grade than that which was applicable to the country. Even if the heaviest grades had not been reduced at the time, with the probable heavy traffic in prospect, it was almost certain that sooner or later the heaviest grades would have been reduced or operated by helper engines, so that it is clear that the heavier minor grades should have been compensated at the outset.

It was also now contemplated to reduce the south-bound grades back on the operated road, between Saxton and Corbin, and also on the Atlanta, Knoxville and Northern for some distance below Knoxville, to the same rate. Thus the plan became a part of a more comprehensive scheme.

Now, it is true that, under ordinary conditions, if the road were laid out contemplating the use of a helper at any point, this adopted ratio of 1% and 0.65% for the helper grade to the ordinary is uneconomical; but, if the helper engine is to be of the same class as the regular engine, the helper grade, ordinarily, could be as heavy as 1.4%, if the grade for the regular engine was 0.65%. But there were very good reasons why this 1% grade against south-bound trains was not altered:

(1) The contract for the construction of the road through the mountain district had been let for some months, and the work was well under way before this change to 34-ft. grades was contemplated.

(2) The 1.4% grade would not have shortened the line at all, and the valley into which that grade would necessarily have descended was so narrow and rugged that there would have been little saving over the 1% grade.

(3) On account of the peculiar conditions under which the road

would probably be operated, it was in no wise certain that
grade would be used as a helper grade. But even if it were,
grade revision was carried back or forward on the old road far
to make up a complete freight division, there would be many
which would not require the service of the helper on a 1% gr
yet certainly would on a 1.4% grade.

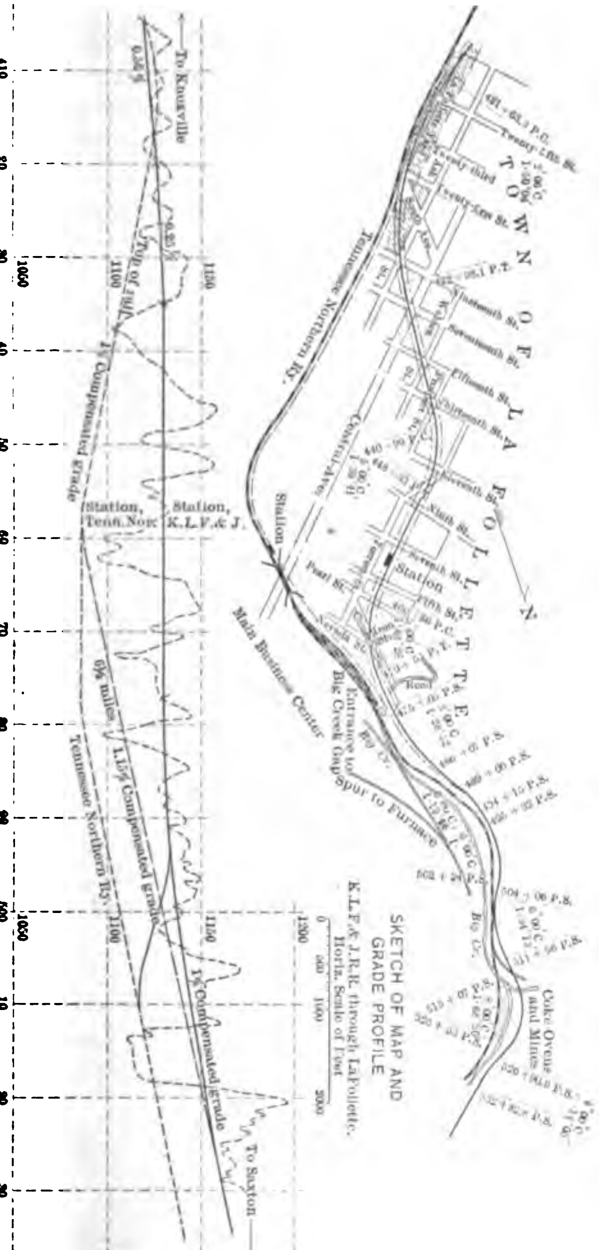
The writer does not pretend that these adopted grades
and 34 ft. south-bound, and 53 ft. and 61 ft. north-boun
studied out and adjusted accurately to the needs of the futur
The probable future traffic was considered, but the grades
were simply the best that the country afforded at a rea
expenditure of from $40 000 to $60 000 per mile, below sul
each of them being fixed by long, continuous ascents—t
materially any one of which for the better could be done onl
expenditure not warranted by the anticipated traffic.

On the supposition that the plan of reducing south-bound
on the old road was not carried out, the scheme of opera
affected by these grades, without using a helper engine, c
outlined roughly as follows:

It was certain at the outset that a spur line would branc
the south end of the Narrows to the excellent, but undevelop
fields of the Clear Fork and Laurel Fork Valleys. It was also
that a spur line would branch off in the neighborhood of Cli
the coal fields in the vicinity of Oliver Springs. Thus, in op
freight trains out of Knoxville would set off empties along th
till they were lightened sufficiently to pull up the 61-ft. grad
of La Follette. Going south, trains would leave the head
Narrows with only such loads as they could pull on the 53-ft.
and would pick up enough loads at La Follette and other po
the route to load them fully into Knoxville.

The writer has been so impressed with the number of in
he has met in his practice in which engineers have lost sigh
important fourth principle, mentioned on page 136, that a
instance, illustrating how some expensive and unnecessary r
fall was avoided, will be cited.

The survey for this road was commenced, under other eng
at La Follette, at the station of the Tennessee Northern, a
ceeded northward. The idea in mind was to parallel the Te


SKETCH OF MAP AND
GRADE PROFILE
K.L.F.& J.R.R. through LaFollette.
Horiz. Scale of Feet
0 500 1000 2000
TOWN OF LAFOLLETTE
Tennessee Northern Ry.
Central Ave.
Station
Main Business Center
Entrance to Big Creek Gap
Spur to Furnace
Coke Ovens and Mines
To Knoxville
To Saxton
Top of rail
1% Compensated grade
Station, Tenn. Nor.
Station, K.L.F.& J.
Tennessee Northern Ry.
1.1% Compensated grade
1% Compensated grade

Northern through the town (see Fig. 4), and to use the station, already built, for both roads. The same parties controlled the Tennessee Northern, all industries, and most of the land near La Follette, and it was considered by them of very great importance to their plan of development that, through the town, the old road should be paralleled by the new. The 6½-mile, 61-ft. grade, from the Cumberland-Clinch divide did not "touch bottom" until just before the station was reached. The profile shows "the hole" in which the station would have been if the original location had been retained. It happened that it was some months after the original line from La Follette northward was run before the writer sent an engineer to La Follette to begin the survey for the extension of the line toward Knoxville, and the idea that the location of the road through the town was fixed as above had pretty well crystallized in the minds of all concerned. This engineer's instructions were to start at the summit south of La Follette (at Station 410, which was an objective point) with the grade elevation of the Tennessee Northern in the summit, and find supporting ground back through the town for a level grade, extending it back into the gap to an intersection with the long 61-ft. grade. The map and profile show the line that was secured. It was about as cheap to construct as the other, gave less curvature, and was some 700 ft. shorter. It placed the station about 300 yds. further from the center of the town than the other station would have been, but good connection with the tracks leading to all the La Follette industries could be had at the summit mentioned and at the point, *F*. This point was just south of the intersection of all tracks on the Tennessee Northern leading to all the coke ovens and coal mines, and was just north of all tracks leading to the three crushers, brick-yards and furnace; and the only land available for yards for the new road, in the vicinity, was at and near this summit at Station 410.

There was vigorous opposition to the new location through the town, however, but the common-sense view of the matter prevailed in the end, and the road was built, as it should have been, on the upper grade line.

The comparative advantage in operation of this upper line was so palpable that it was never attempted to calculate how much more economical it was than the other line. To have put the station for this important town in such a place as was contemplated with 43 ft., vertical, of unnecessary maximum grade immediately on each side of

it, would have been bad engineering, even if the traffic from this point alone was to be considered; but to put a station on a through line in such a place, at which all heavy trains would probably have to stop, when it could be avoided at any reasonable outlay, would have been the height of folly.

After all the contracts for the construction of the main line and the Clear Fork Branch were let, it was found that it required very expensive construction to connect the Oliver Springs line, either at Lee's Ford or just on the north side of the Clinch, 2 miles below Clinton, which were regarded as the only available points. The proposed routes united near Dosset. To reach Dosset from Lee's Ford required 3 miles of road, a bridge over the Clinch, and a tunnel through Black Oak Ridge No. 2. To reach Dosset from the second point required 5 miles of very heavy work and a tunnel through the same ridge. Either plan of building the branch line then would necessitate tunneling this ridge twice, once for the main line north of Clinton and once for the branch line southwest of Clinton. Since it was a fixed fact that the branch line would be constructed, it was suggested that it might be better to turn the main line southwest at a point 3 miles south of Coal Creek, take it through Dosset and make the point of junction for the branch line at Dosset. This plan would save the construction of one tunnel, and either one bridge over the Clinch and the construction and operation of 3 miles of road or the construction and operation of 5 miles of road. But it would miss the town of Clinton. Examination showed that, when the construction of both the main line and the branch line was considered as a whole, the proposed change was advantageous in point of alignment, distance, and economy. The gradients of the main line were not benefited materially by the change, but those of the branch line were benefited very much. To tunnel the ridge on the branch line, with the gradients adopted for it, would have required 2 500 ft. of tunnel, but the gradients now decided upon for the main line required 3 520 ft. of tunnel. Thus, by saving the 700-ft. tunnel and the 2 500-ft. tunnel, and making the 3 520-ft. tunnel, there was 320 ft. more of tunnel to construct, but the cost of the expensive approaches to one of the tunnels was saved.

The town of Clinton was already well provided with railway facilities, and it had not the population nor any industry to give it claim for consideration against such advantages. The last census

showed that it was decreasing in population. Therefore the line was changed to pass through Dosset; and the further advantage was secured that, against south-bound trains, the two principal branch lines have the same limiting gradients as the main line. Thus the road is laid out somewhat on the same principle as that by which a stream departs from its direct course to meet its principal tributaries.

The road, as located finally, is 78.8 miles in length, from Saxton to Asylum Street in Knoxville, making the length of road exceed the straight line distance 55%, instead of 34%, as by the Knoxville and Ohio Branch of the Southern between the same points.

The roughest country encountered was from the head of the Narrows to the Cumberland-Clinch Divide, and here 10° curves were used. Quite expensive construction was necessary on the south side of this divide as far as La Follette, and here a maximum of 8° curves was used. Rough country was also encountered in the 6 miles north of Coal Creek, and on the ascent through Copper Ridge. The sharpest curves used at the last two points were 6°; the remainder of the road was located on light curves, so that the points where curvature would reduce high speeds materially were bunched. From Saxton to La Follette there are ninety-two curves, the total angle turned being 3 717°, or 145° of curvature per mile. From La Follette to Knoxville there are one hundred and nineteen curves, with a total central angle of 3 692°, or 69° of curvature per mile. The minimum tangent was 300 ft., and all curves above 2° were spiraled. The Holbrook spiral, with three different rates of spiraling, was used. For curves under 5°, a spiral increasing 1° in 60 ft. was used (called a 60-ft. spiral). For curves above 5° and under 7°, a 30-ft. spiral was used, and for curves of from 7 to 10°, a 24-ft. spiral was used. It will be noticed that the rate of spiraling is changed sharply in passing from curves of about 4° to those of lesser radius. The reason for this was that curves of 4° and less, with 60-ft. spirals, were intended to be used in open country, and the curves of higher degree, with the 30-ft. spirals or less, were intended to be used only in country where it was necessary to use curvature of such high degree as would necessarily limit the speed of fast trains. The curves were located originally without spirals, but the resident engineers put in the spirals just before staking out the work, so that the road was constructed on the spiraled alignment. It will be noticed that these spirals would all fit in, usually with some distance to spare, on the 300-ft. tangents.

The grade breaks were rounded off by vertical parabolic curves, changing the rate of grade 0.2 ft. per 100-ft. station at summits, and 0.1 ft. per 100-ft. station in sags.

On the final location adopted, there were seven tunnels, in the 79 miles of road, aggregating nearly 10 000 ft. in length. One of these tunnels in the mountain district was located partly on a 10° curve, so that the spiral approach curve, with its varying curvature and rail superelevation, came within the tunnel. The rule used for increasing the tunnel section, so as to give at every point practically the same clearance as on tangents, for an 80-ft. Pullman or dining car, was:

"Widen the tangent section $\frac{13}{16}$ in. per degree, both on the inside and on the outside of the curve. In addition, widen the section on the inside of the curve $2\frac{11}{16}$ ins. per each inch of superelevation."

This particular tunnel was in hard sandstone not requiring lining. The tangent section was rectangular from subgrade to 17 ft. above (16 x 17), with curves of 5-ft. radius in the upper corners. The rule gives a slight excess of clearance on the outside of the curve, which, to some extent, allows for the compression and swing on the car springs.

At the time of writing this paper (December, 1903), practically all the grading, except that in the Knoxville yards, is completed. Several of the tunnels are completed, but the 3 520-ft. tunnel at Dosset cannot be completed, probably, before some time in the summer of 1904. The main line is being built with permanent structures, no timber bridges or bridge supports being used, except four wooden trestles which are to be filled in, eventually, with steam shovel and train.

Of openings on the main line, there are eleven concrete and stone masonry arches of from 12 to 26 ft. span. There are thirty steel bridges, on masonry piers and abutments, and two viaducts of 1 420 ft., total length. These steel bridges consist of three through spans, one of 150 ft. and two of 200 ft., and sixty-seven plate girders of the following kinds, writing their lengths to the nearest 5 ft.: One 40-ft. through, one 45-ft. through, one 80-ft. through, and one 45-ft. double-track deck; and single-track deck girders of the following lengths and number: Two 14-ft., six 30-ft., six 40-ft., eleven 45-ft., one 50-ft., nine 60-ft., twenty-one 70-ft., one 90-ft., and one 120-ft. In these structures there are 43 529 cu. yds. of first- and second- class bridge and arch masonry. In addition, there are 37 248 cu. yds. of culvert masonry.

The total cost of construction of the main line ready for oper exclusive of rolling stock and equipment, is now estimated $5 450 000, or a little in excess of $69 000 per mile. The cost c Oliver Springs Branch is estimated to be $300 000, and of the Fork Branch $93 000.

As will be inferred from the foregoing discussion, in the lay-out road, far more weight was given to gradient and the securing of than to curvature and distance. If economy in operation is in wise proportional to the smoothness of the grades, it is an econ ally located road, considering the country. In seeking a meas grade smoothness for such a purpose, the smoothness of a gra should be taken to vary inversely as the total number of feet, cal, ascended and descended on maximum, or at least on exper grades; but, taking the smoothness to vary inversely as the number of feet ascended and descended, some interesting compar may be shown.

From the crossing of the Clinch, at Clinton, to Knoxville, o Knoxville and Ohio Branch of the Southern, the total rise is 64 and the total fall 601 ft., or a total average rise and fall per mi 59.2 ft. From the crossing of the Clinch, on this line, to Knox there are 290 ft. of rise and 264 ft. of fall, making a total averag and fall per mile of 21.5 ft. Measured as above, the smoothne this new line exceeds the smoothness of the old line, in the country, by 173 per cent.

In this respect, the smoothness of this road compares favo with the smoothness of some prairie roads. The average total and fall per mile from Saxton to Knoxville is 26.2 ft. The ave total rise and fall per mile of one of the principal roads from K City to Chicago, for the first 100 miles out of Kansas City, acros Missouri prairies, is 37.2 ft. per mile. Thus, measuring grade sm ness by this standard, the smoothness of this mountain road, cro the direction of the prevailing ridges and ranges, exceeds the sm ness of this prairie road by 42 per cent.

Vol. XXX. FEBRUARY, 1904. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THEORY OF THE SPHERICAL DOME WITH A HOMOGENEOUS SURFACE, AND OF THE FRAMED DOME; ALSO NOTES ON THE CONSTRUCTION OF MASONRY AND METAL DOMES.

Discussion.*

By Irving P. Church, Assoc. Am. Soc. C. E.

Irving P. Church, Assoc. Am. Soc. C. E. (by letter).—The writer will confine his discussion (except as below) to the first few pages of the paper, involving a demonstration of the stresses in the ordinary spherical dome; which is understood to be homogeneous, of uniform small thickness, and composed of small blocks or voussoirs the surfaces of contact of which are vertical meridian planes on the sides, and conical beds at the top and bottom, each such conical surface being part of the surface of a right cone having a vertical axis and its vertex at the center of the sphere. Since these bearing surfaces are assumed to be smooth, the stress, if compressive, is at right angles to the surface; while, if the stress is tensile (as may occur on the sides), it will be supposed that a horizontal ring of blocks is continuous in substance, so as to keep its form and position. Mr. Church.

While the final general results, stated in Equation 21, for the case

* This discussion (of the paper by E. Schmitt, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for December, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Communications on this subject received prior to March 25th, 1904, will be published subsequently.

Mr. Church. of the open dome (and this includes all the other cases), are the manner of demonstration, in the writer's opinion, is ex obscure and elusive. The first obscurity occurs in Case II 1104.* Here the author states: "At the base of any dome, tv cipal stresses exist, and must balance each other." This m taken as the common loose way of saying "certain forces each other," when what is really meant is that a certain body the action of a certain set of forces, is in equilibrium, or "bal under those forces; but, at the foot of the page it is plainly that these "principal stresses," per unit length of their respecti

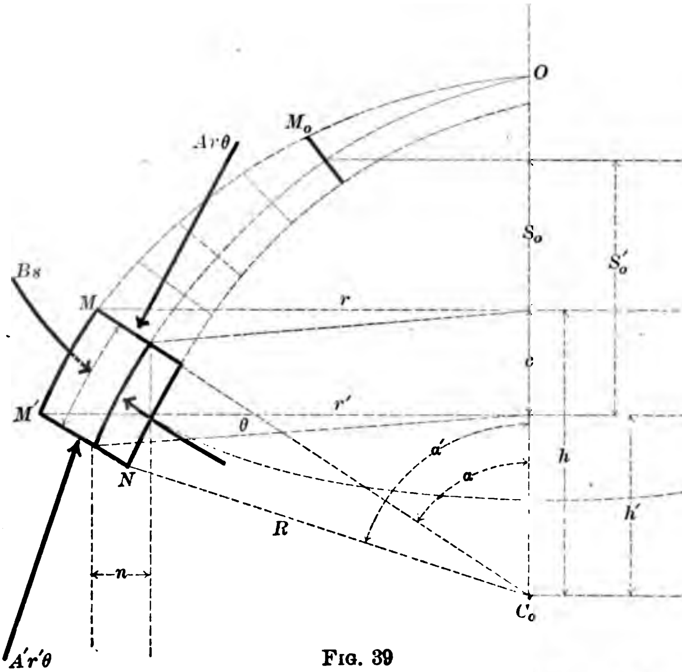


FIG. 39

or surfaces, are assumed equal to each other. The author does scribe, nor represent by diagram, any special body or vous which both these forces act, so as to prove their equality by t of mechanics, but, apparently, makes the assumption of e without adequate reason; that is, that $A = B$. The proof t meridional thrust, A, per unit length of horizontal circumfer equal to $\frac{R^2}{r^2_u} a\, p$, is sound; but that B should be equal to A wo pear to be pure assumption, no valid reason being adduced, t writer is able to discover. The obscurity is deepened by th

* *Proceedings*, Am. Soc. C. E., for December, 1903.

ment that B is the force "per unit length of circumference and for one unit length along the meridian." If B is the "horizontal ring stress" it is difficult to see how it can be measured per unit length of (horizontal) circumference. Perhaps the author might have made himself better understood if this force, B, had been shown, in a diagram or figure, as acting on some definite body. Mr. Church.

As the result of an endeavor to gain some insight into what the author means by the force, B, of Case II, the writer offers the following treatment of the spherical dome, in which the use of trigonometric functions (except in one instance), and of the notation of the differential calculus, have been avoided purposely.

In order that results may apply to any spherical dome, the case of the open dome has been taken; supposed to be divided up regularly (by meridional planes and conical surfaces), into small voussoirs.

The notation used is the same as in the paper (with other symbols added as needed). In Fig. 39, $M\ N$ is a typical small voussoir situated in a ring, the radius drawn to the upper edge of which makes an angle, α, with the vertical axis of the dome, while that to the lower edge makes an angle, α'. A voussoir of the crown ring of this open dome is shown at M_0, in the same "ungula" as $M\ N$. R is the radius of the sphere, while r and r' are the radii of the horizontal circles passing through M and M'. The ungula, $O\ M'\ N$, subtends a small angle, θ, at the vertical axis. Let the small length, $M\ M'$, be denoted by s, its vertical projection being c, and its horizontal, n. C_0 is the center of the sphere. The system of forces acting on the voussoir, $M\ N$, and holding it in equilibrium, consists of the two meridional thrusts from neighboring voussoirs above and below, two lateral thrusts from the adjoining voussoirs on the sides, and the weight of the voussoir itself. This weight is not shown in the figure; it has no horizontal component and hence does not affect the mathematical work (based on Fig. 40) which is to follow. Each of the thrusts is at right angles to the corresponding surface, the two lateral ones being, of course, equal in value.

Since A is to denote the meridional thrust per unit length of horizontal circumference, while B is the side thrust or "hoop thrust" (perhaps tension) per unit length of meridian, the values of the thrusts will be, respectively, $A\ r\ \theta$, $A'\ r'\ \theta$, and $B\ s$; as marked in Fig. 39. By the same process as that pursued on pages 1104 and 1105 of the paper, it may

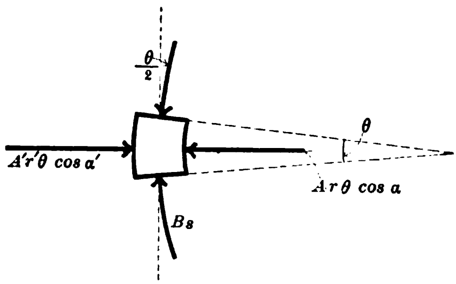


FIG. 40

Mr. Church. easily be proved that

$A = \frac{R^2}{r^2} S_o p$; and $A' = \frac{R^2}{r'^2} S'_o p$, (in which $p =$ the weight of the

per unit of spherical surface); while the value of B is to be detern

Fig. 40 shows the horizontal projection of the system of force ing on the block or voussoir, $M N$, from which it is seen that, the block is in equilibrium, the sum of the radial components parallel to the line bisecting the small angle, θ) of the two f $B s$, must be numerically equal to the difference of the two radial f involving A and A'. If this fact is formulated and the above v of A and A' inserted, and, also, if $\frac{h}{R}$ is written for cos. α, and cos. α', there results $R^2 p \theta \left[\frac{S'_o}{r'} \frac{h'}{R} - \frac{S_o}{r} \frac{h}{R}\right] = 2 B s \frac{\theta}{2}$; and,

$$\text{further, } B = p \frac{R}{s} \left[\frac{S'_o}{r'} h' - \frac{S_o h}{r}\right]; \ldots\ldots\ldots\ldots$$

which,

since $S'_o = S_o + c$, $h' = h - c$, and $r' = r + n$, or $r' = r\left[1 + \frac{n}{r}\right]$

may be written in the form, $B = \frac{p R}{s r}\left[\frac{(S_o + c)(h - c)}{1 + \frac{n}{r}} - S_o h\right.$

But, for an indefinitely small value of n, $\frac{1}{1 + \frac{n}{r}}$ may be replace

$1 - \frac{n}{r}$, whence $B = \frac{p}{s} \frac{R}{r}\left[\left(1 - \frac{n}{r}\right)(S_o + c)(h - c) - S_o h\right] \ldots$

or, $B = \frac{p}{s} \frac{R}{r}\left[S_o h - S_o c + c h - c^2 - \frac{S_o h}{r} n + \frac{S_o c}{r} n - \right.$

$+ \frac{n c^2}{r} - S_o h\Big] \ldots\ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

After cancelling the terms, $S_o h$ and $-S_o h$, it is noted that, c terms remaining in the bracket, all but three contain as factor or more of the small lengths, c or n, while the three in question tain only one; hence as n and c become indefinitely small (and fi zero, since it is wished to discover the value of B for a mere close to the upper corner of the block) the former terms will va as compared with the three;

whence, $$B = \frac{p R}{r}\left[\frac{c}{s} h - S_o \left(\frac{c}{s} + \frac{n}{s} \frac{h}{r}\right)\right].$$

But, from similar triangles, $\frac{c}{s} = \frac{r}{R}$ and $\frac{n}{s} = \frac{h}{R}$;

and, therefore,

$$B = p\left[h - S_o\left(1 + \frac{h^2}{r^2}\right)\right]; = p\left[h - S_o\left(\frac{r^2 + h^2}{r^2}\right)\right];$$

that is, $$B = p\left[h - \frac{S_0\,R^2}{r^2}\right]; \text{ or } B = -\frac{R^2}{r^2}S_0\,p + p\,h \ldots\ldots(82)$$ Mr. Church.

which is identical with the result in Equation 21 of the paper. (The writer, however, sees no occasion for the reservation made by the author in the few lines immediately under Equation 21.)

Now note the effect of supposing the horizontal ring, to which the block, $M\,N$, belongs, to be destitute of weight, all the rings above it still retaining the property of weight. Then, while A remains as before, the value of A' becomes

$$A' = \frac{R^2}{r'^2}\,S_0 p.$$

The same steps being followed as before, it is found that, instead of Equation 79, there is obtained

$$B = \frac{p\,R}{s}\left[\frac{S_0\,h'}{r'} - \frac{S_0\,h}{r}\right], = \frac{p\,R\,S_0}{s}\left[\frac{h'}{r'} - \frac{h}{r}\right]\ldots\ldots(79a)$$

and, instead of Equation 80,

$$B = \frac{p}{s}\,\frac{R}{r}\,S_0\left[\left(1 - \frac{n}{r}\right)\left(h - c\right) - h\right]\ldots\ldots\ldots\ldots(80a)$$

whence, $$B = \frac{p}{s}\,\frac{R}{r}\,S_0\left[h - c - \frac{h}{r}\,n + \frac{c\,n}{r} - h\right]$$

Cancelling the two terms, h and $-h$, in the brackets, and neglecting the term...... $\frac{n\,c}{r}$, which contains two of the small quantities, c and n, and is added to the other terms which contain only one, there is obtained

$$B = \frac{p\,R\,S_0}{s}\left[-\frac{c}{s} - \frac{n}{s}\,\frac{h}{r}\right], = \frac{p\,R\,S_0}{r}\left[-\frac{r}{R} - \frac{h}{R}\,\frac{h}{r}\right];$$

that is, $$B = -\,p\,S_0\left[\frac{r^2 + h^2}{r^2}\right], = -\frac{R^2}{r^2}\,S_0\,p;\ \ldots\ldots\ldots(82a)$$

which is equal to A, but of contrary sign.

A comparison of Equations 82 and 82a shows that the former can be obtained from the latter by simply adding the term, $p\,h$, which is nothing more or less than the horizontal (compressive) hoop stress which would occur in this ring if it were the crown ring of an open dome (see Equation 8, page 1104), in which situation the hoop stress in the ring would be due solely to its own weight. It might now be contended, with some plausibility, that the term to be added to the expression for the hoop stress, B, just found on the supposition that the ring in question has no weight, in order to establish a value for B, holding good in case the weight of the ring is considered, should be this very term, $+\,p\,h$; which is known to be the complete value of the hoop stress in a situation where the ring's own weight is the sole cause of hoop stress. Perhaps some such idea as this was in the author's mind when the treatment of Cases II and III was written;

Mr. Church. but the writer must confess himself unable to apprehend w author means by the stress called B in Case II, *viz.*, "the hor ring stress, B, in the bed-joint of the base" of any dome. Si horizontal ring of voussoirs acts as a base for the portion of th situated above it, it would seem as if the phrase "horizont stress" must mean the hoop stress in any horizontal rin $B = -\frac{R^2}{r^2} a p + p h$; but the author, evidently, considers Case II he has not reached the proper stage for announcing th for B. As before remarked by the writer, the representation definite body, in the way of a voussoir or of a collection of vo some of the forces acting on which involve the B of the autho II, would seem necessary, if his meaning is to be made plain.

The obscurity in the treatment of the force, B, in Cas probably connected with Proposition V, on page 1128. This prop the writer holds to be a fallacy, which, while harmless (as final results) in the author's treatment of the spherical dom rise to an erroneous expression for B in domes of other forms.

For example, in the case of the conical dome, results for wh stated at the foot of page 1134, the author claims

$$A = + \frac{S^2}{2a} p ; \dots\dots\dots\dots\dots\dots$$

and

$$B = - \frac{S^2}{2a} p + \frac{r^2}{a} p \dots\dots\dots\dots\dots\dots$$

(In Equation 71 the writer has put p for p_o and p_u, as is done author on page 1135). But, in applying to the conical dome th treatment as that just given in this discussion for the spherica the writer finds that the results should be

$$A = + \frac{S^2}{2\,a} p ; \dots\dots\dots\dots\dots\dots$$

and

$$B = \frac{r^2}{a} p \dots\dots\dots\dots\dots\dots$$

from which it would appear that in all conical domes, w the angle of inclination, the circumferential hoop stress, B, is compressive.

Of course, if Equation 71*a*, instead of Equation 71, gives t value of B, then the author's conclusions, occupying the whole 1135, are incorrect. According to one of these conclusio horizontal courses of a conical dome the sides of which are than 45° with the horizontal are subjected to horizontal tensio according to Equation 71, as the angle increased the greate be the tension. But, at 90°, the cone becomes a cylinder, of height, in which case, of course, there is no hoop stress o kind in the horizontal courses; but, from Equation 71, thi stress, for an angle of 90°, would be tensile, and infinite in

whereas, from Equation 71a, B = zero, which is known to be true. That Equation 71 is erroneous, would therefore seem to be manifest. Mr. Church.

As a result of the author's general expression for B, he reaches the result that in a truncated conical dome there exists a joint of rupture; but, in the opinion of the writer, this conclusion is altogether erroneous, for the reasons just given.

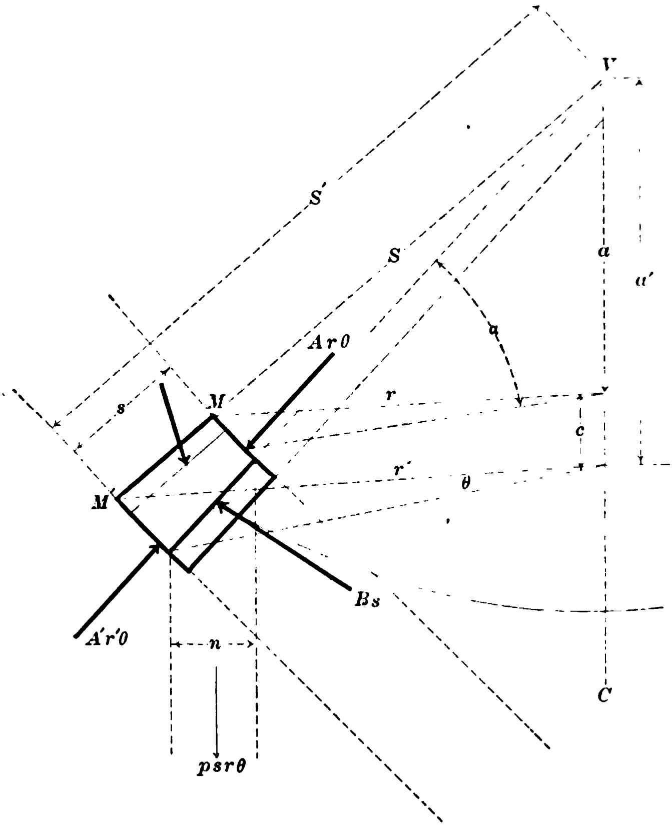


Fig. 41

The detail of the writer's work in deriving Equations 70a and 71a is as follows:

In Fig. 41 is shown a small block or voussoir, $M N$ (of a full conical dome, homogeneous and of uniform thickness), being part of a horizontal ring-course the radius of the upper edge of which is r (of the lower edge, r') and bounded on the sides by two vertical meridional planes, $N C V$ and $M C V$, making with each other a small angle, θ. The elements of the cone make an angle, α, with the horizontal. A

Mr. Church. being the meridional thrust per unit length of "parallel," anc circumferential, or hoop stress, per unit length of meridian, t thrusts acting on the small block are $A\ r\ \theta$, $A'\ r'\ \theta$, and t thrusts (each $= B\ s$). S is the slant height, $M\ V$, and α the a of the part of the dome above M.

First, to find A, consider the part of the dome above weight is $2\ \pi\ r\ \frac{S}{2}\ p$ (where p is the weight per unit area of t vex surface of the cone), and must be equal to the sum of the components of all the thrusts in the curved edge of its base, the of which is $2\ \pi\ r$. Therefore,

$$2\ \pi\ r\ \frac{S}{2}\ p = \left(A\ 2\ \pi\ r\right) \sin.\ \alpha;\ \text{or,}\ A = \frac{S\ p}{2 \sin.\ \alpha};$$

whence, $$A = \left[\frac{p\ S}{2}\right] \div \frac{a}{S}, = \frac{S^2}{2\ a}\ p \ldots\ldots\ldots\ldots$$

In view of subsequent work, a more convenient form for convenient, although "cloaked in the abominable trigonon functions") is obtained thus:

$$\frac{S^2}{2\ a} p \text{ can be written } \frac{p}{2}\ \frac{S}{a}\ \frac{S}{r}\ r;$$

that is, $$A = \frac{p\ r}{2 \sin.\ \alpha \cos.\ \alpha}; \ldots\ldots\ldots\ldots\ldots\ldots$$

and therefore, also, $$A' = \frac{p\ r'}{2 \sin.\ \alpha \cos.\ \alpha}. \ldots\ldots\ldots\ldots\ldots\ldots$$

(This shows that A is directly proportional to the radius r.)

Returning to Fig. 41 (in which the weight of the block, shown as $p\ s\ r\ \theta$, though not needed for subsequent work, as it horizontal component), it is noted that for equilibrium the sys forces obtained by projecting the actual forces on a horizonta will itself be a system in equilibrium. Fig. 40 will serve to re the result of this projection (except that α' is equal to α in the case). In Fig. 40, summing the components parallel to the bisecting the small angle θ,

$$2\ B\ s\ \frac{\theta}{2} = A'\ r'\ \theta \cos.\ \alpha - A\ r\ \theta \cos.\ \alpha.$$

That is, $$B\ s = \cos.\ \alpha\ \left(A'\ r' - A\ r\right);$$

whence, from Equations 83 and 84,

$$B\ s = \frac{p \cos.\ \alpha}{2 \sin.\ \alpha \cos.\ \alpha} \left(r'^2 - r^2\right).$$

Now, $r' = r + n$;
therefore,

$$B\ s = \frac{p}{2 \sin.\ \alpha} \left(r^2 + 2\ r\ n + n^2 - r^2\right), = \frac{p\ n}{2 \sin.\ \alpha} \left(2\ r + n\right.$$

But, as the small distance, n, grows indefinitely small, it va

added to $2r$, so that Mr. Church.

$$B = \frac{n}{s} \frac{p\, r}{\sin.\ \alpha} = (\cos.\ \alpha) \frac{p\, r}{\sin.\ \alpha} = p\, r \text{ cotan. } \alpha = p\, r \frac{r}{a}.$$

, finally,

$$B = \frac{r^2}{a} p. \dots\dots\dots\dots\dots\dots\dots\dots (71a)$$

s easily shown that in case the conical dome is truncated, er with or without a lantern, the value of B given by Equation nains unchanged; *viz.*, B still $= \frac{r^2}{a} p$.

e value of A, however, would be different from that given by ion 70a, if the dome were truncated or had a lantern.

nay be of interest to state that the results, for the conical dome, d by the writer, are in exact agreement with those given by ne in his "Applied Mechanics." Rankine, however, does not t details of derivation, but merely outlines a general method l domes, making use of the principles of the differential us.

Vol. XXX. FEBRUARY, 1904.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A DESIRABLE METHOD OF DREDGING CHANNELS THROUGH RIVER B

Discussion.*

By Messrs. F. B. MALTBY and WILLIAM GERIG.

Mr. Maltby. F. B. MALTBY, M. Am. Soc. C. E. (by letter).—The data pr by the author on the extent of the commerce on the rivers of pean Russia are extremely interesting, and, to the write surprising.

The writer, as Superintendent of Dredging Operations on t sissippi River below Cairo, has had some experience which ma interest, and presents the following, not in criticism of the pa as possible additional information on the subject.

On the Mississippi River, the location of the channel to be d across the obstructing bar is of much more importance than th or size of the cut to be made. An improperly located cut will maintained, whatever its shape or size, while, on the other h the cut is located so as to get the maximum effect of the curren its axis it will probably be maintained, if not enlarged, duri low-water season. No rule for this location can be laid down. only be determined by study of the conditions at each individu and, very largely, is a matter of experience.

Usually, when dredging is required most urgently on the sippi, the river is falling very rapidly, and the problem is to o the channel as quickly as possible.

* Continued from January, 1904, *Proceedings*. See October, 1903, *Proceed* paper on this subject by S. Maximoff, Assoc. M. Am. Soc. C. E.

During the last dredging season the river at Cairo fell from a stage of 11.7 ft. on December 2d to 2.8 ft. on December 20th, or almost 9 ft. in eighteen days, and the rate of fall during the interval was fairly uniform. As the ruling depth which it was desirable to maintain over the bars was reached at about 7 ft. on the Cairo gauge, and as the number of dredges available just at that time was limited, it was important that work should be done as rapidly as possible. As an instance of how rapidly this work is done, the writer cites the instance of a bar which, on the arrival of the dredge, had a possible channel of 7 ft. over it. Where the dredged cut was located, the least depth was about 5.5 ft. In 68 hours after arrival at the bar a channel not less than 200 ft. in width and 12 ft. in depth had been made. The distribution of time was as follows: Mr. Maltby.

Placing plant	$4\frac{1}{2}$ hours.
Changing cuts	$3\frac{1}{2}$ "
Repairs	1 hour.
Dredging	59 hours.

During this time six cuts were made having a total length of 4 440 ft., and an average depth of cut of 8 ft. The depth of channel given above is the least depth on the bar after the dredging was completed; there was a depth of about 15 ft. along the axis of the dredged cut. This channel was maintained and improved steadily both in depth and width during the remainder of the season.

Possibly, more rapid work might be cited, but the foregoing will give a fair idea of the amount and kind of work done. Evidently, under these conditions, there is no chance for any fine regulation of the depth of the suction shoe to allow for a slope on the bottom of the cut in either direction.

The writer wishes to criticise the method proposed by the author only in its applicability to the Mississippi River; theoretically, his reasoning seems to be sound, and, if conditions can be found which follow the assumptions, the results should be as predicted.

William Gerig, M. Am. Soc. C. E. (by letter).—The writer agrees with the author's statement "that the dredge should be properly designed for the work to be performed." It should not only be an efficient dredge for dredging river channels, but should also be designed so that it can be moved quickly from one bar to another without much loss of time in towing and placing the plant. On the Mississippi, it often requires only from 24 to 48 hours to dredge one bar, and then the dredge and plant must be moved quickly to another bar. This part of the design of a dredge is often overlooked, or thought of little importance, by the designing engineer. Mr. Gerig.

Dredging channels through river bars is usually necessary at certain periods, or when the river is low, and on a river like the Mississippi,

Mr. Gerig. where a fall from 12 ft. above to the mean low-water mark has oc in two or three weeks, the main object is to dredge the ch through the bars as quickly as possible, so that navigation will interfered with. When the Mississippi continues to fall slowly a long period, many of the bars are deepened by the current not need dredging; but, where the fall is rapid, the bars do not fast as the river falls. This increases greatly the amount of w be done, and the number of places to be dredged. It is then ne that the channels to be dredged be located so that a channel of width and depth be obtained with a minimum amount of dredg

A dredged channel in the Mississippi, if located properly, is permanent during the low-water period, provided no rapid rise in the stage of the river has occurred, and that obstructions, s sunken snags, logs or barges, which are moving along on the b have not lodged in or near the head of the channel. These obstru often cause the channel to be filled. After a flood, or even rapid rise and fall in the river, it happens sometimes that the large bar in the place where, a few months previously, the chan the river flowed.

At the beginning of the past low-water season, the least w the Mississippi, between Cairo, Ill., and New Orleans, La., was bar known as "Peters Towhead Crossing", which is about 40 mi low Memphis, Tenn., where there was a depth of only 11 ft. channel when the river was some 16 ft. above the mean low mark on the Mhoon gauge. If the river could have fallen su to the mean low-water mark, there would have been a bar 5 f extending entirely across the river.

The Dredge *Delta*, of the Mississippi River Commission's fleet, was placed on this bar at that time and dredged a channel wide and 20 ft. deep, by making five cuts. The width of each c 32 ft., and the ridges left between the cuts were removed by t rent. This channel remained for some thirty days, when, after of some 4 or 5 ft., it showed signs of filling up. When the rive menced falling, the dredge was again placed on this bar at the pr location, and made five more cuts to a depth of 20 ft. As the ri ceded slowly, this channel was enlarged by the current, and wh river had fallen to about 1 ft. above the mean low-water mark Mhoon gauge, some three months after dredging, although the been several fluctuations in the stage of the river, there still re a 9-ft. channel of ample width. The bars on both sides of this c were dry at the lowest water.

It will probably be of interest to note that this dredge has a s head arranged so that dredging can be done either up stream, dropping down stream over the bar. The arrangement is very and works well. It has been found that when the bar to be dr

is composed of ordinary river sand, the down-stream method of dredging is the more effectual, for the following reasons: Mr. Gerig.

First.—That when the cut is completed, all the material has been removed, and there remains a full-depth cut. In dredging up stream the material put in suspension by the agitator is deposited in the cut under the dredge, while in dredging down stream, the material deposited under the dredge is removed as the dredge proceeds down the stream.

Second.—That when the first cut is made down stream, and extends from deep water above to deep water below the bar, there is a decided increase in the velocity of the current in the cut, which assists the dredging materially by the erosion of the sides and bottom, and thus reduces the number of cuts to be made.

Third.—That more progress is made by down-stream dredging, since there is no danger of breaking the hauling cables or machinery, and, consequently, the operator will feed the dredge to its full capacity. This is demonstrated by the record this dredge made on the "Joe Echols Bar" during December, 1903. The material was ordinary river sand, free from drift and logs, and the average depth of cut was 3.5 ft. An average of 250 ft. of cut per hour was made in dredging down stream, and 230 ft. while dredging up stream.

Fourth.—By being able to dredge both ways, much time is saved, in changing cuts and in placing the dredge, since all that is necessary is to move the dredge over to one side of the cut previously made, reverse the suction head and begin dredging.

From experience gained on the Mississippi, the writer thinks it would be impossible to lay down a prescribed method for dredging, for the reason that there are different conditions, even on the different bars on the same river, which have to be overcome. It seems to be best, however, that at least the first and last cuts should be made down stream with the current, and that, where there is ample time to do the work, the upper end of the channel be widened so as to funnel the water into it.

Vol. XXX. FEBRUARY, 1904. No

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advan in any of its publications.

METHOD USED BY THE RAILROAD COMMISSION, OF TEXAS, UNDER THE STOCK AND BOND LAW, IN VALUING RAILROAD PROPERTIES.

Discussion.*

By E. L. Corthell, M. Am. Soc. C. E.

Mr. Corthell. E. L. Corthell, M. Am. Soc. C. E. (by letter).—The writer, s 1887, has had some knowledge of the facts referred to in this pa has been familiar with some Texas railroads and their terminals, is acquainted, more or less, with the physical conditions of the so ern and western portions of that State.

He has no doubt whatever of the general beneficence of the T railroad law, beneficent generally to all parties except perhaps old-time railroad promoter.

The law, and generally its just operation, has cured many un gated and notorious evils. Not only has the public in Texas benefited, but also the investor in railroad securities from outsid State. The people of Texas now have just and uniform rate transportation, and the investor knows what he is purchasing, may be reasonably sure of a return on his investment.

* This discussion (of the paper by R. A. Thompson, M. Am. Soc. C. E., print *Proceedings* for January, 1904), is printed in *Proceedings* in order that the expressed may be brought before all members of the Society for further discussio Communications on this subject received prior to March 25th, 1904, will be publ subsequently.

Mr. Corthell.

In the methods of valuation described, and these are about the only strictly engineering questions involved in the paper, there appear to be some serious objections.

Both old railroads—that is, those which existed prior to the passage of a law in 1894—and new roads, are valued according to the judgment of the State Engineer, "allowing current market prices for labor."

Would it not be more reasonable to obtain the contract prices paid by the company in constructing its railroads, and the actual cost from its books when doing the work by its own day labor? Are the railroad officials so untrustworthy and deceitful that they could not be trusted to give correct figures? One would hardly expect that the officers of a railroad company would enter into collusion with the contractors in order to show a larger cost than the actual; if so, then the law could reach them and punish them for fraudulent practice.

In valuing pre-existing properties, the author states that "no additional allowance was made for the value of seasoned roadbed, etc." A most important item in the real cost of an old road is thus eliminated from the valuation, without further reference to it or explanation, while every railroad engineer who has had the experience in maintaining railroads knows how costly "seasoning" is. As an illustration, it may be stated, from reliable reports, that, considering all the various lines of the Southern Pacific System in Texas, for the ten years prior to 1894, the cost of "seasoning," that is, physical betterments, changes in alignment, restoring washed banks, raising roadbed, rebuilding after washouts (a common experience in Texas), raising track, etc., etc., cost \$4 734.30 per mile of track. This appears to be all the more important when considering the extremely low valuation which the Commission has placed on the road. Referring to Table No. 1, it is found, for instance, that the 919.06 miles of the "Galveston, Harrisburg and San Antonio" (one of the principal lines of the main line of the Southern Pacific) are valued at \$16 142 298, or only \$17 564 per mile, whereas the "seasoning" alone has cost one-fourth of this.

Again, the cost of "legal and engineering expenses and superintendence" is allowed at the rate of 5 to 6% of the total estimated value of the road, which is entirely too low to cover these important and costly items; and where are the other costs, such as contingent expenses (which an engineer would generally estimate at from 15 to 20% of the estimated cost), general expenses, right-of-way agents, and all the multitudinous employees who must be upon every railroad of any importance during its preliminary and constructive periods? And yet, the estimate on which to base the permitted issue of stocks and bonds is made upon the report of an engineer who goes over the road with a profile and estimates his quantities from center heights. Any expert engineer, who has had to examine and report

Mr. Corthell. upon the value of railroad properties, knows how utterly inadequate such a method is, to get at the actual cost of a railroad, even approximately. This, the writer knows by his own experience in examining and reporting upon about 600 miles of railroad in this same State of Texas.

Considering all the items that go to make up the actual cost of a good railroad, with all its appurtenances, from the right of way to the rolling stock, the valuation of $15 000 to $20 000 per mile is entirely inadequate to cover it, in Texas, at least.

All the old roads, that is, all roads existing before the Commission made its valuations, are and probably always will be, debarred from the issuance of any more stocks or bonds, no matter how many and how costly may be the physical improvements or equipment they put into their properties, or wish to put into them. Although the valuation of the "Galveston, Harrisburg and San Antonio" is given as $16 142 298, this road, at the time of its construction, had a stock and bond issue of $52 612 400, divided nearly equally between stock and bonds.

No dividends have ever been earned on the stock, and, no doubt, most of it was what may be called watered stocks; but until, by betterments and general additions to the value of the property, its valuation by the Commission has reached, on the same mileage, $52 612 400, no stocks or bonds can be issued—a rather hopeless future—so that, to make any increase in equipment or any substantial improvements, there is no method by which the road can borrow any money.

The writer believes that all the companies of old Texas railroads would have been perfectly satisfied with the work of the Commission, in respect to this feature, had a fair estimate of their properties been made at the outset, so that they might earn the legal rate of the law on their investment, *viz.*, 6 per cent. This refers to the fact that the Commission fixes the rates so that the companies may earn the legal rate of 6% on the valuation of the properties as made by the Commission.

Texas is a great State and a rich agricultural country, and it has a great future. No doubt, any hardship, which unreasonable methods have brought about, will disappear in time, with juster methods of valuation, and a better appreciation of the work which the railroads are compelled to do, and the expenses they have to meet.

The legislators who framed the law and the Commission which enforces it, were actuated by the best of motives and for the general good of all interested, especially the public, which suffered under the former conditions. The writer desires to say that, from a personal acquaintance with the honored Chairman of the Commission from the outset, he knows of no more conscientious and patriotic man than Judge Reagan.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM WARD REED,* F. Am. Soc. C. E.

DIED JANUARY 10TH, 1904.

William Ward Reed, son of William Wyndham and Elizabeth Ingram (Smith) Reed, was born in Ashtabula, Ohio, on April 1st, 1824. He was of New England descent, his great grandfather, Colonel Seth Reed, a physician at Uxbridge, Massachusetts, having commanded a regiment at the battle of Bunker Hill. Colonel Reed, his wife and two sons were among the pioneer settlers of Erie, removing thence from Ontario County, New York, in 1795.

William Ward Reed was educated at the academies of Ashtabula, Ohio, and Erie, Pennsylvania. Here he acquired a good, practical education, but added largely to this in later life by his careful reading of general history and many branches of science, and especially by his studies in the higher mathematics, thus laying a broad foundation for his future profession as a civil engineer.

From early life Mr. Reed was active and energetic in whatever he undertook, whether as student or man of business, and was especially thorough in the studies and practical matters pertaining to his chosen profession.

His first service as a civil engineer was in the location and construction, in 1849–50, of the Erie and North East Railroad, now a part of the Lake Shore and Michigan Southern Railroad, and while engaged in this work he was advanced to the position of Assistant Civil Engineer. In September, 1851, he went to Canada, and was engaged for four years on the Ontario, Simcoe and Huron Railroad, between Toronto and Collingwood, Ontario. During the following year he was engaged in the construction of the harbor at Collingwood, and was next in charge of the construction of the Niagara Road, from Clifton to Niagara-on-the-Lake. During the next two years he was Contractor's Engineer on the Sarnia Branch of the Great Western Railroad.

On returning to his home in Erie, in 1858, he built by contract an aqueduct over the Elk Creek, on the "Pennsylvania Erie Extension Canal," a work of more than ordinary engineering difficulty. After completing this work he was elected Superintendent of the same canal, in 1859, a position which he held until the canal was sold to the Pennsylvania Railroad Company, and by them closed and abandoned.

In 1867, when The Board of Commissioners for the construction of a system of water-works in the City of Erie was constituted, Mr. Reed

* Memoir prepared by A. H. Caughin, Esq.

was made a member of the Board, and subsequently was elected their President. He continued to hold this important position for twelve years, and it was under his administration that the works were built and the first pump installed; and, later, his engineering skill and experience were called into play in the construction of the great reservoir on Twenty-sixth Street. Subsequently, he was engaged for a number of years, either as contractor or engineer, on various railroads, until he retired from business. He was one of the founders and original stockholders of the Second National Bank of Erie, and was for many years one of the Directors and, for a part of this time, Vice-President.

Mr. Reed, notwithstanding his busy life as civil engineer and constructor, was always a public-spirited citizen, and liberal in his support of charitable and benevolent enterprises. He was one of the Board of Managers of the Hamot Hospital, and was long a prominent member of the Masonic Fraternity. He was a member of St. Paul's Episcopal Church, of which he had been a Vestryman for more than twenty years. Deeply interested in the political questions and movements of the day, he was an active member of the Republican party and a pronounced advocate of the protective policy of that party; and for three successive terms he received the support of a large majority of the Republicans of his county as their nominee for Congress, but suffered defeat in the nominating convention of the district.

Mr. Reed was of quiet and reticent habits, but always positive and outspoken in his views when circumstances demanded their expression. Of a kind and generous spirit, he invariably won the affection and esteem of the men employed under him. He was never married, but in his home life was a most tender and devoted son and brother, and toward his associates in social and business life a faithful friend.

Endowed with a very retentive memory, and giving himself up, in the quiet retirement of his later years, to a diligent course of historical and scientific reading, he became almost an oracle of information on many subjects. His business judgment was so sound that he was frequently consulted in important matters, and his advice was highly regarded by his business associates. Of pure and upright character; resolute of will, self-poised and self-reliant, bearing resolutely the misfortunes that came upon him, through the dishonesty of others, in the latter portion of his business career, and enduring uncomplainingly the severe sufferings of his last days, William Ward Reed passed away, deeply mourned by all the members of his family and by the inner circle of his many attached friends, bearing with him the undiminished respect and esteem of the community which, in many capacities, he had long and faithfully served.

Mr. Reed was elected a Fellow of the American Society of Civil Engineers on December 20th, 1872.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS.

PLATES.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A PHENOMENAL LAND SLIDE.

By D. D. Clarke, M. Am. Soc. C. E.

To be Presented April 6th, 1904.

The gravity system of water-works, constructed during the years 1893 and 1894 by the Water Committee of the City of Portland, Oregon, included a series of four reservoirs for supplying the different districts of the city. Reservoir No. 1, with a capacity of 12 000 000 galls., and No. 2, with a capacity of 20 500 000 galls., supply the East Side District; and Reservoir No. 3, with a capacity of 16 400 000 galls., and No. 4, with a capacity of 17 700 000 galls., supply the West Side District. Two of these reservoirs, Nos. 3 and 4, on the West Side, were built in a narrow ravine occupying a portion of the City Park, about two miles west of the business center of the city. The lower reservoir has an elevation of 220 ft. and the higher one 290 ft. above mean low-water level of the Willamette River. These two reservoirs were formed by dressing down the banks of the ravine in which they are located; and, since their completion, a serious derangement of the western slopes of both reservoirs has taken place, owing to a movement of the adjacent hillside.

The magnitude of this movement was not understood at first, but

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

since been found to extend for nearly the full length of both oirs, a distance of about 1 100 ft. This distance may be called proximate width of the slide at its lower or eastern end. At the r western end it is about 400 ft. wide, and its length from east t is approximately 1 700 ft. The depth, as determined at various , ranges from 50 to 112 ft., and the surface area approximates es. The volume of the moving mass has been estimated at 00 cu. yds.

ing into consideration the characteristic features of this nent, its length, breadth and depth, and the uniformity of the nent of the sliding mass, it may be truthfully called "A Phe- al Land Slide." It is the purpose of this paper to describe the s and explorations which have been made during the last nine for the purpose of determining the dimensions of this slide and bable cause, and to aid as well in devising a plan for the cure difficulty.

e writer has been engaged in the service of the Water Committee March, 1893, and for the past seven years has had engineering of all construction work. He has therefore had personal edge of the work from almost the very beginning, and the sur- nd explorations described in the paper have been made largely his personal supervision.

order to reach a correct understanding of the situation of these oirs, and the reasons which led to their location at the point , a few words regarding the physical characteristics of the region e necessary. The City of Portland is largely built on the lower of a range of hills bordering the Willamette River on the west. distance of between one and one and a half miles from the busi- istrict the slope is quite gradual, rising in that distance to an ion of from 150 to 250 ft. Beyond that point the hills rise more tly and reach an elevation of from 800 to 1 000 to 1 200 ft. in a istance from the river of three miles, or less. See Plate IV, a of the territory.

owing down the eastern slope of this range of hills there are sev- mall streams which discharge into the river within the city limits gh brick conduits of large size. These streams, though small, furrowed out channels for themselves, which, on their upper es, vary in depth from 40 to 200 ft. below the general level of djacent ridges. One of the largest of these streams is known as

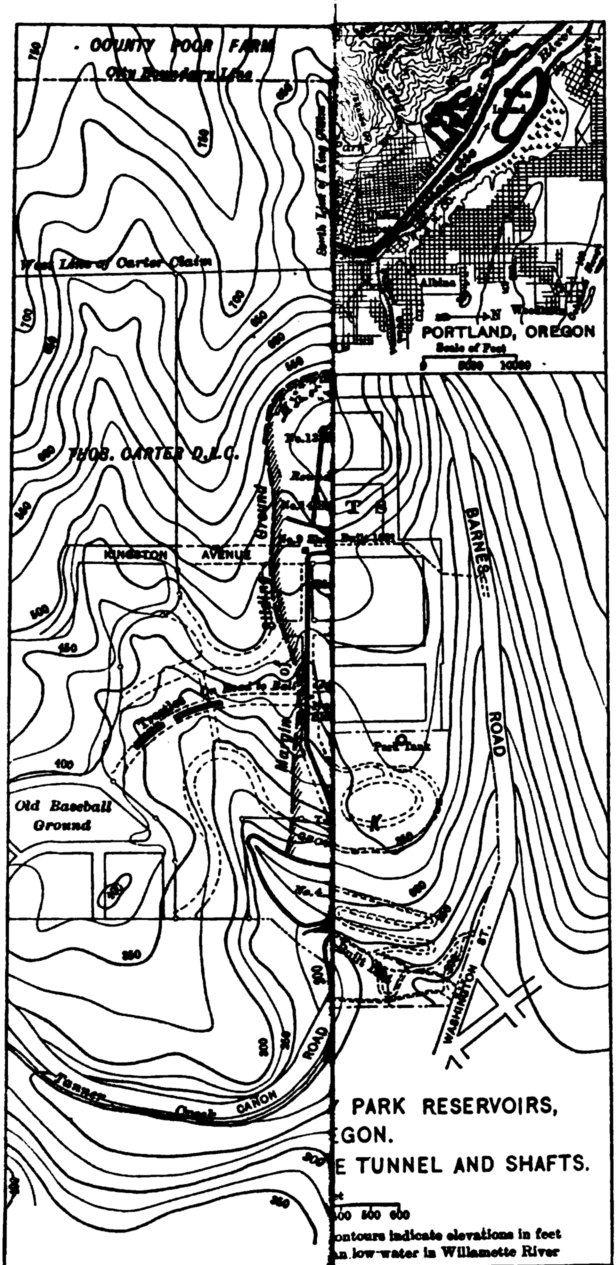
Tanner Creek, its lower portion being now confined in a brick sewer, approximately 6 ft. in diameter. The upper or western end of this sewer is near the southeast corner of the City Park, and only a few hundred feet from the site of Reservoirs Nos. 3 and 4, to which this account refers. Above the head of this sewer the valley of the south or main branch of Tanner Creek is about 150 ft. wide, with side slopes from 1 on 1 to 1 on 3 or 4 horizontal, and with almost perpendicular bluffs of basaltic rock at a few points.

The reservoirs described are upon the north branch of Tanner Creek, which flows from the northwest through a corner of the City Park and unites with the main creek at the head of the brick sewer to which reference has been made. The total length of this branch is somewhat more than one mile, and it has a total fall of about 500 ft. During the dry season the flow is insignificant, and, for several months, it disappears almost entirely.

The selection of this ravine, for the site of the two reservoirs required for the west side of the river, was due chiefly to its favorable location for securing the desired elevation at the most accessible point for making connection with the system of pipes then in use. Besides, the land for one reservoir was already owned by the city, and the additional ground, needed for the second or low-service reservoir, adjoining the City Park and combined with it, could be purchased upon favorable terms.

There are other ravines of a similar character both north and south of Tanner Creek, but none more accessible or apparently more favorable as a reservoir site. The location of the reservoirs upon level ground, or outside of some ravine, was not regarded as feasible, within the required limits as to distance and elevation. At the point chosen for the reservoirs, the original bed of the ravine was quite narrow, from 20 to 50 ft., with sides sloping back about 1 on 1½ to 2½ horizontal, to a height of about 50 ft. on the east, and on the west about 100 ft. above the bottom.

The material composing the hillside, as far as appeared from the borings and examinations made before the excavation of the reservoirs was undertaken, was yellowish sandy clay upon the surface, but only a few feet in depth, with basaltic rock underneath. The character of the underlying rock was not then known, further than what could be seen at several points where a bluff a few feet high showed rock at the surface, and at one point, 200 yds. down stream, where a perpendicular



[...] PARK RESERVOIRS,
[OR]EGON.
[...]E TUNNEL AND SHAFTS.

[Scale of Fe]et
[...]00 500 600
[C]ontours indicate elevations in feet
[above mea]n low-water in Willamette River

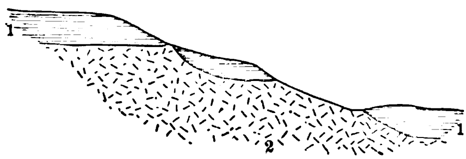
bluff 50 ft. high was exposed. From these indications the general basaltic character of the rock was known. Where exposed, the rock was full of seams, but appeared to be sound and in place.

Along the banks of Johnson Creek, which flows in the next ravine north of Tanner Creek, about one-third of a mile from Reservoirs Nos. 3 and 4, similar bluffs of basalt can be seen, a road-metal quarry having been opened at one point exposing a vertical wall, from 50 to 75 ft. high, which shows plainly the general character of the material.

Here it may be of interest to note the following account of the geological features of this region, quoted from "A Geological Reconnoissance in Northwestern Oregon," by Joseph Silas Diller.*

"If the whole of western Oregon subsided 200 ft. in all parts, so as to restore at least in some measure the conditions of land and sea which obtained during the Pleistocene epoch, it is evident that the sea would flow in over the land, making a large bay of the Columbia and extending up the valley of the Willamette as far as Salem" (50 miles south from Portland). "The Pleistocene water body in its general outlines must have resembled Puget Sound, and to designate it specifically, as already indicated, Professor Condon called it Willamette Sound. The fertility of the Willamette Valley is largely due to the sediments deposited in it during the time it was a sound, and some of the plains and prairies may then have been formed.

"The data for the accurate determination of the depth of the water in Willamette Valley have not yet been fully made out, but the evidence already known to Professor Condon indicates that the water extended as far south as Spencers Butte, three miles from Eugene" (125 miles from Portland). "Judging from the height of the terraces on the Columbia, near the mouth of the Des Chutes" (90 miles east from Portland), "he estimated the depth of the water over the place where the city of Portland now stands to have been 325 ft. This may well be, and yet when we study the deposits of which the hills about Portland are composed, a much greater depth of water is indicated. During a brief stay in Portland a rough section was made up the slopes of the ravine from Gambrinus" (or Johnson Creek). "It is illustrated by Fig. 15. The city is



SECTION OF PORTLAND HEIGHTS, NEAR GAMBRINUS RAVINE.

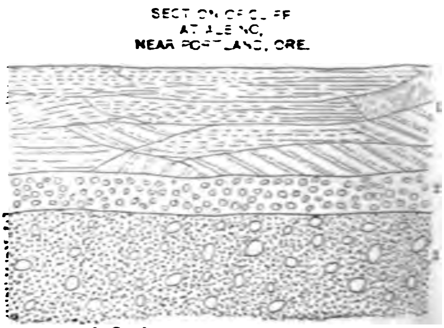
1 = Clay.
2 = Basalt.

"FIG. 15."

*Seventeenth Annual Report, United States Geological Survey, 1895-1896, Part I., pp. 85 and 486.

largely upon the modern flood plane of the river, and is, at least at a number of points—for example, on Washington Street, near the Oregonian Building—made up chiefly of clay. The lower portion of the hill, above the general level of the city, is made up of basalt, with occasional masses of fine sediments, showing traces of stratification. The upper portion of the hill, extending from the top of the lava, at an elevation of about 310 ft., to the general plain above, which is at an elevation of nearly 660 ft. above the sea, is fine, argillaceous sediment closely resembling the loess of the Mississippi Valley. It is in places distinctly stratified and was evidently laid down under water. If this material was deposited in the Willamette Sound of Condon, as appears to be the case, the depth of water at Portland must have been not less than 600 ft. At present too little is known of the geology of the Portland region to assert that the fine sediments on the heights immediately west of Portland were deposited at the same time as those along the coast.

"At the north end of East Portland, near Albino, a bluff exposes the section shown in Fig. 16.



1 = Sand.
2 = Coarse Gravel.
3 = Sand, Pebbles and small bowlders.

"Fig. 16."

"The 40 ft. of coarse sand above is well stratified, but irregular and cross bedded. This, with the 4 to 10 ft. of conglomerate next below, indicates strong, shifting currents. The lower 30 ft. of the exposure is made up of sand, pebbles and bowlders irregularly intermingled. At the base of the cliff, and occasionally within it, are found bowlders of soft gray or yellowish sandstone, very like the Tertiary sandstone exposed at various places in western Oregon. No fossils were found at this point, but Dr. David Raffety gave me a fragment, collected from the gravel at Brooklyn Mills, that contains *Arca microdenta* Conr., a common Miocene form. Brooklyn Mills is at the south end of East Portland. The bluff, in general composition and position, is practically a continuation of the one at Albino. The fossils found at Brooklyn Mills are apparently in a small bowlder derived from the Miocene, and indicate that the gravels in which the bowlders occur are of later age than the Miocene. They are doubtless Pleistocene, and probably younger than the high-level sediments on the opposite side of the river. The fossiliferous Miocene in place is not known to the writer nearer Portland than the Scappoose, in Columbia

FIG. 1.—LOOKING SOUTH FROM RIDGE NEAR CABLE RAILWAY BRIDGE, SHOWING RESERVOIRS NOS. 3 AND 4, PART OF SLIDING LAND AND SHAFT NO. 1.

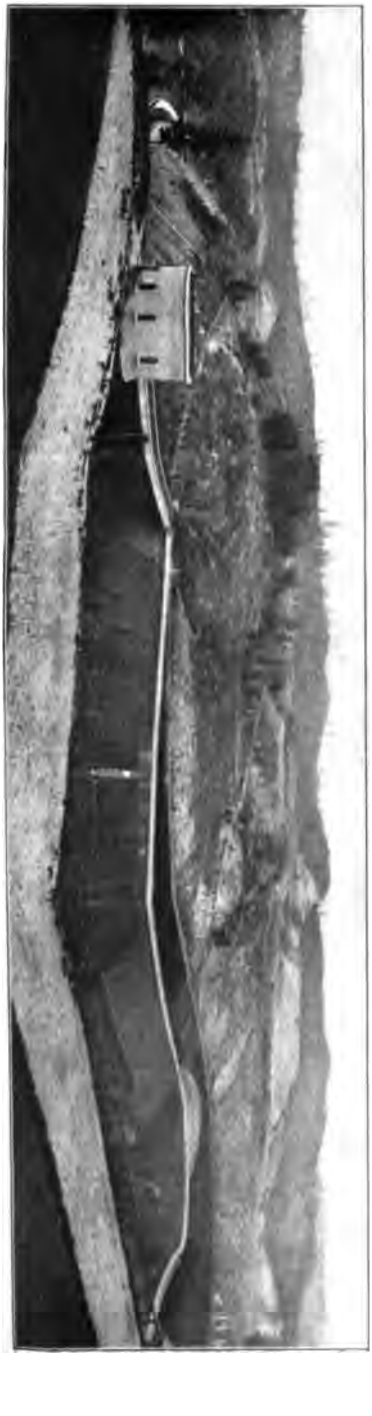


FIG. 2.—LOOKING WEST FROM CITY PARK, SHOWING RESERVOIR NO. 3 AND THE SLIDING LAND. TAKEN SEPTEMBER 23D, 1897.

County, or Dilley, in Washington County, about 25 miles away. It is probable, however, that the same series of strata occur at no great distance south of Portland, and in the Willamette Valley and in the hills to the westward, and, furthermore, they probably extend beneath the city, where they are covered by later deposits."

In the foregoing extract, it will be noted that Professor Diller comments on the absence of fossils in this vicinity, as far as at present known, from which the age of the formation could be determined. As bearing upon this point, the writer would here mention a fossil which was found, on December 31st, 1898, in one of the excavations at the site of Reservoir No. 3, the upper reservoir at the City Park, at an approximate elevation of 218 ft. above the sea level. The fossil was found embedded in a deposit of blue, sandy clay, 41 ft. below the surface and 17 ft. above bed-rock, in connection with some small pieces of wood and a few water-worn pebbles.

Concerning the classification of this fossil, Mr. F. A. Lucas, of the National Museum, Washington, D. C., writes as follows:

"It is the left lower molar of a camel. Its worn condition renders it very difficult to identify, but it is probably *Camelops kansanus* Leidy. This species has been ascribed by both Leidy and Cope to the Pliocene, while Wortman reports it from the Pleistocene."

During the fall of 1891 and the following winter, or nearly two years prior to the commencement of reservoir construction, a cable railway was built from the business portion of the city westerly to the southeast corner of the City Park. Thence it continued its westerly course, crossing the ravine in which the reservoirs are now located and ascending the steep slope of the ridge for a distance of about 1 500 ft., and thence, turning to the north along Kingston Avenue, it followed a nearly level grade for about 1 200 ft. to the terminus of the line. In its last course along Kingston Avenue the road crossed two ravines, the first upon a 25-ft. embankment, and the second upon a timber trestle, 40 ft. high and 300 ft. long, the latter being across the main ravine in which the reservoirs are situated.

The photographs, Fig. 1, Plate V and Fig. 1, Plate VI, show the reservoirs and the sloping hillside on the west from different points of view, the cable road and the bridge across King ravine, to which reference has already been made.

The view shown in Fig. 1, Plate V, was taken on September 28th, 1897, looking south from the point of the ridge northeast from the

cable railway bridge on Kingston Avenue. At the left can be seen the gate-houses at Reservoirs Nos. 3 and 4 and the valley of the south branch of Tanner Creek. In the center appears the terraced ground at the left of which can be seen the cluster of small firs marking the southwest corner of City Park. In the center of the terraces can be seen the temporary pump-house marking the site of Shaft No. 1. On the right can be seen the railway bridge, and, farther on, the outline of the "round top," near the head of the sliding ground, can be traced.

The photograph shown in Fig. 1, Plate VI, was taken on September 22d, 1897, looking north along the cable-railway track on Kingston Avenue from a point on a ridge south of the moving ground. The 90° angle in the track is shown in the foreground. A short distance beyond the center is the twisted track at the northern margin of the moving ground. Kings Heights, north of Johnson Creek, appear in the distance.

The cable road was completed about May, 1892, and put into operation at once. During the construction of the road, the owners of the property west of the City Park made contracts for grading and terracing their property, with a view of offering their lots for sale, the cable road having been extended to this tract solely for the purpose of making this property accessible and desirable as a residence district.

As has been stated, the operation of the cable road was begun in May, 1892, but the running of cars was discontinued during the following winter. The operation of the road was again commenced about May, 1893, and continued until September, 1893, when it was finally suspended owing to the removal of the bridge across the ravine at the site chosen for Reservoir No. 4. A change was made necessary by the beginning of work on the reservoirs, and the owners of the property preferred to abandon the line rather than reconstruct the bridge to span the reservoir, and protect it properly, in accordance with the terms of their right-of-way agreement.

During the grading of the property west of the reservoirs, to which reference has already been made, ridges were cut down and several small ravines filled, without providing proper underdrainage, and, in the two years following, other ravines were filled with materials furnished to the property owners by the contractors who were excavating the reservoirs. In the bottom of two of the larger of these ravines, rough

Fig. 1.—Cable Railway on Kingston Avenue.
September 22d, 1897.

Fig. 2.—Cable Railway East of Shaft No. 6.
June 24th, 1898.

No. 3.—Looking North from the Summit of the Ridge near the Old Ball Ground, Showing

log culverts were built, but, evidently, little or no care was taken to prevent the earth from sifting through the chinks between the logs, and the drains soon became choked and useless.

At one point in the ravine west of the cable road the embankment formed a shallow pool. For the purpose of draining this pool, as well as street intersections lower down the slope, the property owners constructed a terra cotta pipe sewer, some 8 or 10 ins. in diameter, laid a few feet below the surface, and leading eastward to the park boundary.

The principal part of the work just outlined was completed before the excavation for the reservoirs was begun. The excavation for both reservoirs was commenced in October, 1893, and carried forward simultaneously at both points during the following winter, but the work was not entirely completed until September, 1894.

During the winter of 1893–94 municipal affairs occupied the attention of a large committee of citizens, styled "The Committee of One Hundred," and during this time the new water-works, then in process of construction, came in for a share of the criticism to which all branches of the City Government were being subjected. The water-works being entirely under the control of "The Water Committee," consisting of fifteen of the leading and substantial men of the city—named for the position in the legislative act authorizing the work—their management was not to be impeached, but the engineers of the Water Committee were criticised by some members of the Committee of One Hundred for recommending the location of important reservoirs in the City Park. As a result of these criticisms, the Water Committee called upon their engineers for a report on the condition of the work. In compliance with this request, the engineers submitted the following statement:

"On account of the elevation of the headworks on Bull Run, the fall required to overcome the friction of the water in the pipe and the allowable pressure on the city mains and the submerged pipe under the Willamette River, the reservoir must be placed at an elevation of about 300 ft. above the base of city grades.

"By survey made from the southern to the northern boundary of the city, it was ascertained that all the lands at this elevation were on a steep hillside; that the reservoir could only be constructed in ravines in which the required capacity could be obtained by dams of moderate height, and the depression in the City Park was best suited for the

purpose of a reservoir, and was the only one into which the water could be discharged without encountering great and almost insuperable difficulties in the extension of the supply main from the crossing of the Willamette River westward. From borings and test pits made on the side slopes of the ravine, it was ascertained that the material was a light surface soil, underlaid with clay and hardpan resting on solid rock, as shown on plans and sections recently laid before the Water Committee and Messrs. Woodward, Honeyman and Foley of the Committee of One Hundred.

"The dam proposed will rest on solid rock at the sides and bottom, and the lining of the sides on clay, hardpan or rock, for which purpose all the loose surface will be removed. Around the reservoirs, about 5 ft. above the surface of the water, there will be a berm 10 ft. in width, along which will be laid culverts and drains to carry away the water running from adjacent lands.

"It was stated by Mr. Woodward, in conference with the Committee on Monday last, that he did not apprehend danger from failure of the dam or leaks from the reservoir, but that the lands of the King Real Estate Company sloping downward to the west line of the City Park, and resting on a bed of clay, underlaid by rock, that this clay when exposed to the action of water would become soft and slippery, so that the whole hillside would slide down into the upper reservoir, and be dumped into the lower, causing the destruction of both and loss of life and property from the discharge of water contained in the reservoirs. He also stated that should there be a dip in the strata of rock at the foot of the hill and a rise toward the reservoir the danger of a slide would be obviated.

"The construction of roads and terraces on the lands of the King Real Estate Company, and the wash of small streams caused by recent heavy rains, furnish ample data to observe the nature of the soil and the underlying strata of clay and rock. From the top to the bottom of the hill, the rock crops out in places, indicating that there is no great depth to the surface soil. At the points where the rock is exposed there are no indications of a slippery subsoil or tendency to slide. The slopes are not deep, and extend, not to the reservoirs, but to a depression at the foot of the hill, on the west line of the City Park, along which there is a road leading to the bridge in the City Park below the reservoir. On the western edge of the reservoir there is another road, and between the two there is a knoll extending 400 ft. north of the dam. Looking from the east side of the reservoir toward the deer park, the land appears to rise continuously to the top of King's Hill, but, as above stated, there is a road and depression on the other side of the knoll, from which there is a gentle slope to the top of the hill.

"Within the deer park the depth of the surface is not known, but

the rock crops out on the east side and west side, and to the north, and the cost would not be great to strip the rock so there would be no danger of a slide or damage to a reservoir should a slide occur. To the north of the deer park and on the land of the King Real Estate Company, there had been a surface slide extending down to the upper edge of the reservoir, but this slide, as well as the others which have occurred at both reservoirs, can be traced to the action of a small stream of water which has run over the surface soil and saturated it to the clay on which it rested. This, and all the others, are small and local, and can be easily remedied.

"The side slopes of the reservoir have not yet been cut down to firm materials, and the wash of the surface soil by the heavy rains of last winter gives to the excavation a very rough appearance; but there have been no large displacements or slides, and, in our opinion, there is no danger in the future of any slide of sufficient magnitude to injure the reservoirs."

The bridge referred to in the foregoing report crossed the ravine immediately in front of Dam No. 3, affording access to the elk barn and enclosure which formerly occupied the summit of a small knoll 200 ft. from the west end of the dam.

The depression near the west line of the City Park was filled, during the reservoir construction, with materials excavated from the basin of Reservoir No. 3. See Fig. 2, Plate V.

The publication of this report seemed to quiet the fears which had been aroused by the statements made before the Committee of One Hundred, and public interest in the matter soon began to wane. The final report of the Committee of One Hundred, submitted to the citizens several months later, contained no reference to the reservoir investigation.

In the light of subsequent developments, the foregoing report of the engineers of the Water Committee appears to indicate a failure to comprehend the magnitude of the difficulties with which they had to contend, but, for such failure, the writer has no words of criticism to offer. He was at that time a member of the engineering staff, and, although indirectly connected with the work in question, he was acquainted with the circumstances of the case, as then understood, and was in entire accord with the position taken by the engineers in their report.

The engineers state in their report that it was claimed by some that the hills west of the reservoirs were of clay resting on rock; that the

clay would slip and slide when wet; and that, in consequence of such slides, the reservoirs would be suddenly filled and the water they contained spilled out, causing great loss of life and property.

Presumably this opinion was based upon what could be seen upon the surface near the reservoir, in addition to what was known of the material at points in other ravines where slides had occurred in former years. That no person at that time had any conception of the existence of a deep-seated movement, of the magnitude that has since been developed, is made evident by the fact that they predicted surface slides which would suddenly fill the reservoirs and cause death and loss of property by the flooding of the low ground below the dams.

In examining the ground adjacent to the reservoirs, the engineers found only indications of small surface slips. These they thought could be rectified, and the ground made stable at small expense, and they therefore reported in favor of continuing the work. It can now be seen that the engineers were mistaken in their judgment, and failed to realize the magnitude of the forces arrayed against them. The slide, which was even then doing its destructive work, was not near the surface of the ground, and hence not apparent to the ordinary observer. Even those who had early knowledge of a movement upon different portions of the "sliding land," as it is called, failed to connect and unite them into one harmonious whole, and so far failed to estimate properly the extent of the movement which was taking place.

The surveys and borings which determined the selection of the City Park as the site for the reservoirs were made chiefly during the year 1887, supplemented, however, by additional borings made early in the year 1893.

The work of reservoir construction was pushed rapidly during the spring and summer of 1894, grading for reservoir basins, work upon concrete linings and the massive concrete dams for both reservoirs being in progress at the same time. The excavations for the reservoir basins were not completed until about September 1st, 1894.

In the early part of August, and before the west slope of Reservoir No. 4 had been cut down to its intended position, a slip in the bank was noted about midway on the slope opposite a point where the basin was about 30 ft. deep. (This point is marked by a cross in Fig. 2, Plate VII.) The slopes of the reservoir basin were 1 on 1½.

Fig. 1.—Reservoir No. 4. Cracks in Parapet Wall and West Slope. Taken September 28th, 1897.

Fig. 2.—Reservoir No. 4. Crack in Outer Edge of Inclined Roadway, and in Face of Slope Above Sub-Retaining Wall, Taken September 28th, 1897.

The line of this slip was found to be along a seam between strata of blue and yellow clay, the yellow clay being above the blue. The slope of the seam was found to be 1 vertical and 10 horizontal, the dip being westward into the hill.

Concerning the character of the deposits of blue and red or yellow clay, which were uncovered at this point, and which have figured largely in all subsequent explorations, the following may be said: The deep yellow and red clays found at different points are, as a rule, quite plastic and contain little sand. Evidently, they were formed by the decomposition of the lava, which at different periods has overflowed this region, and were colored by the iron in the rock. Some beds were found where this process of decomposition seems not to have been complete, for the texture of the material was coarse, containing grains and small fragments of the rock incorporated with the clay, but the finer materials were all of the same reddish or yellow color. The blue clay differed from the red in some of its characteristics. When found in thin seams near bed-rock, it was tough and plastic, but when found in considerable bodies at higher levels it contained quite an appreciable portion of fine sand. When dry it was hard to pick, and a vertical bank would stand without support. When placed in water it soon crumbled into an incohesive mass. The general characteristics of this clay indicate its sedimentary origin, in some deposits small pieces of wood and water-worn pebbles being found in connection with it. In his later treatment of this material, the writer has described it as "blue quicksandy clay" as best indicating its character.

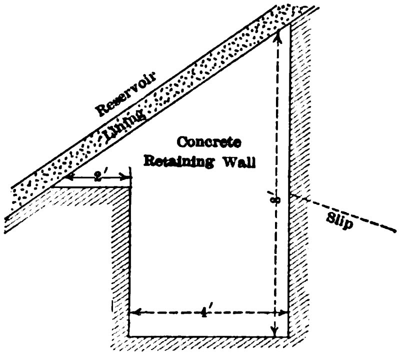
Owing to the loose material on the face of the untrimmed bank at Reservoir No. 4, the extent of the slip, referred to above, was not determined for several days, and it was thought to be merely a local slip which extended but a few feet above the berm at the top of the reservoir slope. In fact, there was, at about this time, and near the same point, a local slip extending a few feet into the bank, which was subsequently refilled and a part of the parapet wall and slope lining built over it.

After a few days' observation of the movement of this slide, it was found that the break in the ground extended about 200 ft. south and 100 ft. north from the point where it first appeared, making a total length along the reservoir slope of approximately 300 ft. When first

observed, and for several days thereafter, the movement was at the rate of ½ in. per day, but this did not continue long.

The plan adopted to overcome this difficulty was to build a concrete retaining wall in front of the slip and below the reservoir lining. This wall was of the dimensions shown in Fig. 1, for a total length of about 320 ft.

At the time this wall was being built, a drainage tunnel was constructed in the rear of the wall, following as closely as possible the seam dividing the blue clay from a deposit of yellow clay with a mixture of loose rock, which was found to be water-bearing. The tunnel extended the full length of the buttress, and from 50 to 100 ft. westward therefrom. Several small pockets of water were tapped and drained into the sewer through pipes laid in this tunnel during its construction.



CONCRETE RETAINING WALL, BELOW RESERVOIR LINING AT "SLIP"

FIG. 1.

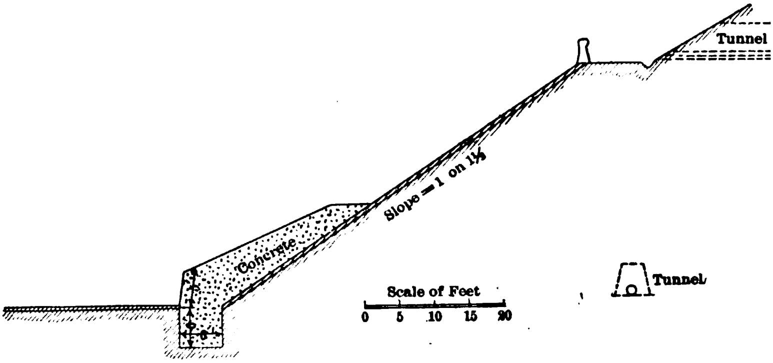
After the completion of this wall it was observed carefully for some days, and, no further movement appearing, it was thought that the retaining wall and drainage tunnel acting in conjunction had been effective in checking the movement. Accordingly, the lining of the west slope was completed and the reservoir made ready for use in accordance with the original design. The filling of the reservoir was completed on December 17th, 1894.

The work at Reservoir No. 3, the upper or high-service reservoir, will be described next.

Early in September, 1894, the work on this reservoir had progressed so far that the lining had been completed on the bottom and the west slope, when the discovery was made that the concrete lining in the bottom had bulged up at one point, just north of the center, from some cause then unknown. A few days later, September 8th, this break was repaired, but before the end of the month another one was discovered in the bottom, near the foot of the west slope and opposite the former break. This time the difficulty was thought to be due to quick-

sand and clay in the bank behind the facing of more stable materials upon which the slope lining had been laid.

To meet the difficulty encountered at this point it was decided to construct a concrete buttress wall about 100 ft. in length, and of the general dimensions shown in Fig. 2.



CONCRETE BUTTRESS AT RESERVOIR NO. 3.
FIG. 2

At the same time that the construction of this buttress wall was in progress, work was begun on a drainage tunnel to run into the bank west of the reservoir, at the berm level, for the purpose of draining away any water which might reach the reservoir from that direction. The construction of the buttress wall and the drainage tunnel at the berm level, occupied about one month, and occasioned some delay, but the reservoir was completed and ready for use early in December.

The photograph, Fig. 2, Plate V, was taken on September 22d, 1897, looking to the west from a point in the City Park, about 160 ft. northeast from Gate-house No. 3. On the left can be seen a portion of Reservoir No. 4, with the rip-rap on the west slope above the roadway. In the center can be seen the gate-house and a portion of the dam and basin of Reservoir No. 3, with the graded slope extending to the Park boundary. The clump of trees at the left of the center is at the southwest corner of the City Park.

The highest point of the ridge shown near the center is approximately 2300 ft. distant, and 400 ft. above Reservoir No. 3.

On the right can be seen a portion of the buttress built against the west slope of Reservoir No. 3.

No further movement of the bank was observed until the very day, December 14th, 1894, the reservoir was being filled, when two cracks in the bottom were discovered near the south end of the buttress completed but a short time before, but the full significance of these new cracks was not discovered until after the reservoir had been filled. Directions were given at once to have the reservoir emptied, which was accomplished on December 20th.

From the examination which followed the draining of the reservoir it was concluded that the difficulty was caused by the presence of water in the adjacent bank west of the reservoir basin, and steps were at once taken to construct a drainage tunnel behind the reservoir lining, as had been done at Reservoir No. 4 some months before, but this time on a grade parallel with the bottom of the reservoir basin.

This tunnel had its outlet connecting with the sewer at a point between the power-house and Dam No. 3, and was located along the margin of the bed of loose rock and clay which explorations had shown to exist in the bank on the west of the reservoir. The construction of this tunnel occupied several months, and when it had been completed along the entire western margin of the reservoir to its northern extremity, at no point more than 100 ft. from the foot of the reservoir slope, it was thought that a satisfactory solution of the whole difficulty had been reached. Drain pipes were therefore placed in the bottom of the tunnel, and the excavated material was replaced, in the expectation that all needed drainage and protection work had been done.

While this tunnel work was in progress, surveys were begun for the purpose of determining the extent of the movement at both reservoirs. The indications of pressure against the reservoir walls were more pronounced at Reservoir No. 4 than elsewhere, but even there they were not so serious as to prevent the basin being at least partially filled from December, 1894, until the following September, The first evidence of pressure against the walls of the completed reservoir was noticed about the middle of January, 1895, or a few weeks after the basin was first filled, when a small crack appeared in the west parapet, near the old cable railway crossing. Other cracks soon appeared, increasing in number and size, until the middle of April, when the parapet was broken in several places and the lining was cracked, parallel with and about 6 ft. below the berm walk, for a

distance of about 300 ft. An examination made at this time showed that the upper part of the lining and a portion of the parapet wall had been lifted clear of the ground and the wall tilted to the west.

The view shown in Fig. 1, Plate VII, was taken on September 28th, 1897, looking west from the north end of the dam at Reservoir No. 4, and shows the cracks in the parapet wall and the west slope, indicating a movement of the bank. The position of the concrete retaining wall, built under the slope lining during the construction of the reservoir, is indicated by the upper line of horizontal cracks about midway on the slope. The retaining wall for the roadway and the rip-rap face of the original excavation are shown above the parapet wall. Breaks in the rip-rap, due to the slide, can be traced at the upper left margin.

The photograph shown in Fig. 2, Plate VII, was taken on September 28th, 1897, looking south along the west slope of Reservoir No. 4, from a point on the parapet wall in front of the power-house. It shows the crack in the outer edge of the inclined roadway and in the face of the slope above the sub-retaining wall, and also the breaks in the parapet wall with the concrete slope lining crowded nearly to the top of the wall by reason of the pressure of the moving ground. The maximum observed movement of the parapet wall from December 31st, 1894, to October 11th, 1897, was 3.24 ft.

Soon afterward, that portion of the lining above the crack was removed, and after this had been done the parapet returned nearly to its original position. In doing this work, a break was found in a 4-in. pipe, which had been laid under the berm walk for the supply of a series of jets around the margin of the basin; and, at another point on the same pipe, a branch was found to have been plugged with concrete instead of iron, and it was thought that these defects, by allowing the escape of water, had been instrumental in causing a settlement under the concrete lining and parapet. It was also recalled that the breaks appeared first near the point where a short section of the parapet had been built upon made ground, on account of a small slide which occurred before the reservoir was completed. These facts are mentioned simply to show that all were groping in the dark in search of some explanation of what was taking place before their eyes. The surveys made at this time indicated that a slight movement of the parapet wall had taken place, but it was not considered sufficient to explain the cracks in the concrete lining and parapet.

During June and July, 1895, the slight movement which had been noticed ceased so nearly that it was deemed safe to begin the repair of the reservoirs in order that they might be used. Accordingly, August and September were devoted principally to this work. While repairs were being made at Reservoir No. 3, additional drains were laid under the floor and on the west slope, as it was thought that they would prove a safeguard to protect the concrete work. This was a vain hope, however, for the repairs on the reservoirs had hardly been completed, and the basins partially filled with water, before it became apparent that the pressure from the adjacent banks was as great as ever. This was shown by the appearance of new cracks in the lining and parapet walls, and by the increased movement, as indicated by a re-survey of the range lines established during the previous January.

The repairs referred to above included an increased thickness of concrete upon the reservoir floor, making a total thickness of about 10 ins. Prior to this time the foundation of the buttress moved with the pressure. The subsequent movement caused the wall to break at the angle, from 4 to 6 ft. above the reservoir floor. See Figs. 1 and 2, Plate VIII.

This view was taken on September 28th, 1897, looking west from a point on the east parapet of Reservoir No. 3, opposite the buttress. It shows the horizontal crack in the buttress and the principal breaks in the west slope and parapet. The photograph shown in Fig. 2, Plate VIII, was taken on September 28th, 1897, looking south from a point on the parapet at the north end of Reservoir No. 3. The cracks in the buttress are shown on the left. At the right margin can be seen the northern limit of the broken parapet and slope lining. The maximum observed movement of the parapet from December 31st, 1894, to October 11th, 1897, was 1.69 ft.

From statements already made, it will be seen that, from the first, numerous theories were advanced to explain the cause of the difficulty with which the engineers were contending. At one time, the movement at Reservoir No. 4 was thought to be due entirely to a deposit of "quicksandy clay" behind the buttress which had been built under the lining before the reservoir was completed. The tunnel was then draining considerable water from the vicinity of this deposit, but apparently without effect.

By direction of the chief engineer, during March, 1895, the writer corresponded with Robert L. Harris, M. Am. Soc. C. E., since

FIG. 1.—RESERVOIR NO. 3. HORIZONTAL CRACK IN BUTTRESS, AND BREAKS IN WEST SLOPE AND PARAPET. TAKEN SEPTEMBER 28TH, 1897.

FIG. 2.—RESERVOIR NO. 3. CRACKS IN BUTTRESS, AND IN PARAPET. TAKEN SEPTEMBER 28TH, 1897.

deceased, inquiring if his process for handling quicksand could be used to advantage in solidifying the material in situations similar to this, which was described to him. Mr. Harris stated in reply that he did not think that his process would be applicable, and said he thought the hillside was moving forward on a seam in the clay and that the movement was caused by a "hidden spring," as occurred in a case in his own practice where he ran a tunnel to the spring, and, by removing the water, stopped the slide.

The cause of the movement suggested by Mr. Harris was not deemed to be within the bounds of possibility, for the thought of the movement of the whole mountain side was an alarming one, but when, during the autumn, it was noticed that the movement was still in progress, even after the lapse of several months of dry weather, a new and more vigorous search was begun, in order to determine the point where the slide could have originated.

The writer was cognizant of the statements that had been made, to the effect that the whole hillside was part of an old slide, but not for a long time, and only after repeated examination, was he able to determine, even approximately, the boundaries of the ground which might be said to form part of an "old slide." The ground adjacent to the reservoirs was examined carefully for surface cracks which it was thought would certainly appear at some point within reach of an ordinary slope upward from the reservoir bottom. That such surface signs should not be found within a distance of 600 ft., or that the slope of the break should be flatter than 1 on 3, was then undreamed of and not deemed to be within the bounds of possibility.

Gradually the limits of the examination were enlarged, until, on September 23d, while exploring the vicinity of the old cable track on Kingston Avenue, the writer detected a slight bend in the rails.

During the week following this discovery further explorations were made, and instrumental surveys as well, which resulted in locating the head of the slide in a marshy depression in the hills about 600 ft. west of the cable track, and some 1 700 ft. or more from the reservoirs. The "round top" or knoll apparently at one time formed a part of the ridge. The marshy depression in front of the knoll, to which reference has been made, is semi-circular in shape, about 300 ft. long and from 30 to 60 ft. wide. The rim of the basin at the southeastern end was not more than 2 or 3 ft. above the level of the marsh, and therefore the water stored could not have been of a greater depth. When dis-

covered, there was no water standing on the surface, but the ground was moist in places and covered with swamp grass, weeds and brush. Subsequently, the peaty formation was found to be from 15 to 20 ft. deep, with clay underneath.

That the movement must have been in progress for months, or years, was shown by the deflection in the alignment of the cable track at the center of the slide, which amounted to 2.2 ft. maximum, as determined by the instrumental observations, assuming that the track was laid out originally as a tangent for the entire distance along Kingston Avenue, which is known to have been the case. The examinations also showed the entire absence of all surface cracks, parallel with the reservoirs, at any point between the reservoir basins and the swampy ground at the head of the slide. A sign of the movement was found at one intermediate point, however, as shown in Fig. 2, Plate VI. This point was at an angle in the cable railway in its western course up the hill, and about 500 ft. from Reservoir No. 4. The angle in the track at this point is about 18°; the distortion of the rails, however, when first noticed, was about one-third as great as shown in the photograph, the latter not having been taken until June 24th, 1898, or nearly three years after the movement was first discovered.

The photograph, Fig. 2, Plate VI, looking west, shows the angle in the cable-railway track just east of Shaft No. 6. The pressure of the slide has warped the track out of position, the rails having been bent to the south. When this movement was first observed, September 25th, 1895, the lateral movement of the rail amounted to about 6 ins. As shown in the photograph, the rail is 18 ins. from the original position, measured at an angle of 60° from the horizontal. A similar movement of the north track has taken place, but it does not show in the photograph. Toward the top of the picture a vertical bend in the south rail of the south track can be distinguished. This point is at the east side of the "ball ground" landing, where there is a break in the grade. It has been observed that all rail joints along this section of the track are tightly closed.

As the result of these examinations, it was decided to begin at once a series of instrumental measurements to determine whether the sliding ground was really as extensive as recent developments indicated. In pursuance of the plan then adopted, several range lines were established, with their terminal points widely removed from the vicinity of

the suspected ground, each line having a number of intermediate stations located so as to be observed easily and accurately, and at the same time be on supposedly moving ground.

During the latter part of 1895, and the first six months of 1896, twenty-nine of these range lines were established, about half of which were observed at intervals of about one month for a period of from three to five years, and several have been observed to the present time. The lines, at first, were established so as to cover a wide range of territory, for it was thought possible that the movement of the hillside might be more extensive than then appeared from any visible signs, and therefore several of the ranges were extended to the summits of the highest ridges in sight upon the north and south sides of the supposed sliding ground. After a few months' trial the observation of these long-range lines was discontinued, for it soon became evident that the movement was confined to the ground lying to the west of the reservoirs and within the limits of the ravines extending west from the City Park.

Some range lines were also established early in 1895, with reference to the movement of the parapet wall. When it became apparent that the movement extended for a considerable distance from the parapet walls, preference was given to observations on lines having points set in the ground, for it was noticed that the pressure against the parapet wall was not uniform, and that, in places, the wall was being tilted to the west.

In 1895, when most of these range lines were established, no surface signs of movement, other than the curvature in the cable-railway tracks and the breaks in the lining and parapet walls of the reservoirs, were apparent at any point, excepting a few small cracks in the ground in the vicinity of the marsh at the head of the slide. The surface of the ground, between the reservoirs and the cable road on Kingston Avenue, was searched carefully for cracks which might indicate the extent of the movement, but, contrary to all expectations, no crevice could be detected along the high ground adjacent to the reservoirs and parallel with them, and, strange as it may seem, no such crack has ever been observed, with the exception of one, about 125 ft. long, near the site of the old elk barn and about 200 ft. west of the power-house and Dam No. 3. This crack did not appear until May, 1896, or eighteen months after the reservoirs were excavated, and could

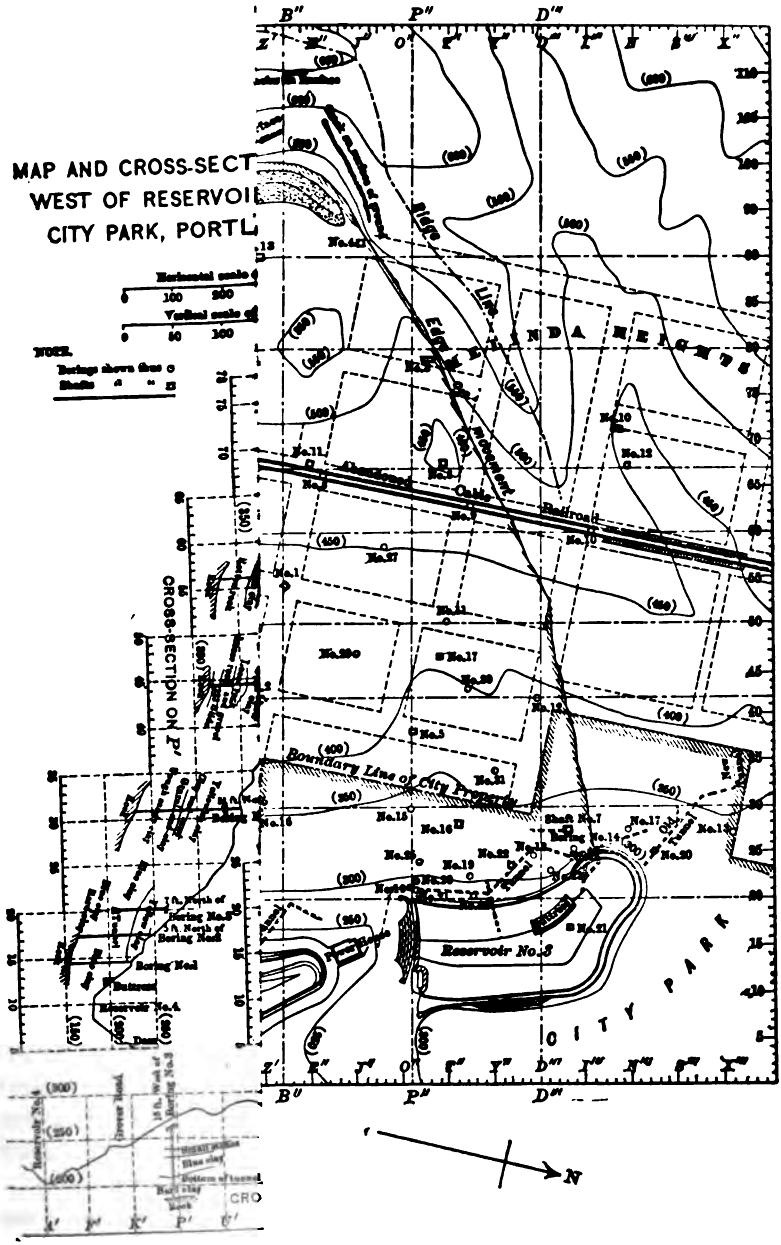
not be seen long, for, having been only a trace along the surface, it was obliterated entirely in a few months. Other cracks, of a larger size, were found, about this time, around the margin of the depression, or marshy ground, at the head of the slide, and these increased to such an extent that during 1897 the outline of the movement in that vicinity could be traced by an almost continuous break in the ground.

In the autumn of 1895, or as soon as it became apparent that the movement extended to such a great distance from the reservoirs, the chief engineer directed that arrangements be made to determine the depth of the slide, as well as the area, in order to ascertain whether or not the movement was along or near the surface of bed-rock.

The plan decided upon for securing this information was to drill through the overlying material, and into the rock, with an ordinary well-boring machine, a water-jet being used to remove the earth and pulverized rock. This work was in progress from September 27th, 1895, until March 31st, 1896. In all, twenty-five holes were drilled, aggregating 1 710 lin. ft. (See Plates IX and X.) These borings were located along the cable track, and eastward, and, subsequently, two of them were found to be outside of the limits of the moving ground. The contract for this work specified that the holes should be drilled through the overlying strata of clay and loose rock, and 5 ft. into the solid bed-rock, so as to make it certain that the drill did not stop at each small boulder it encountered. The holes were 4 ins. in diameter, and were cased with wrought-iron pipe which was driven until the lower end was in close contact with what was thought to be bed-rock.

The prices paid for this work were $1.25 per linear foot for earth or loose material, and $3.00 per linear foot for solid rock, where the holes were drilled deeper than the 5 ft. specified, as was done in some instances. These prices included the use of the plant, and labor only, all other expenses, for casing, and for wood and water, for the use of the engine, being extra, the total cost averaging $1.68 per linear foot.

After the holes had been drilled and cased, the next thing was to devise some plan by which the depth at which the movement was taking place could be determined with accuracy, and the following was decided upon: To measure the depth of the holes, a small pipe, 1 in. in diameter, was fitted in 10-ft. sections for ease in handling. At each end of one of these 10-ft. sections there was fitted a flange,


MAP AND CROSS-SECT
WEST OF RESERVOI
CITY PARK, PORTL
Horizontal scale
Vertical scale
NOTE.
Borings shown thus
Shafts
CROSS-SECTION ON P'
Abandoned Cable Railroad
Boundary Line of City Property
Reservoir No. 3
CITY PARK
Reservoir No. 4
N

about $3\frac{3}{4}$ ins. in diameter, which nearly filled the inside of the well casing. To this flanged section of pipe the other sections were coupled for a handle, and with this handle the flanged section was passed down the well casing to bed-rock.

A trial of this sounding rod was made soon after each boring was completed, and in all cases it would pass freely to the bottom of the hole. Subsequently, this trial was repeated at intervals of about one month, but, after one or two trials, it was found that the pipe flanges would stick in the casing and prevent the rod from reaching the same depth as upon the first trial. This was understood to mean that a bending of the well casing, caused by the movement of the slide, was taking place at about the depth reached by the flanged rod, the flanges on the bottom section preventing the rod from passing the bend in the pipe.

Subsequent explorations showed conclusively that measurements of the depth of the slide made with these rods were practically correct. In three instances where bends in the casing occurred the pipes were dug out afterward and were found to be badly bent or broken within 1 ft. of the depth determined by the sounding rod. In most of the borings made the movement was found to be taking place at or near the surface of the bed-rock, and at depths varying between 50 and 112 ft. below the surface of the ground. In some of the borings, water would rise in the casings after they were completed, indicating the presence of water pockets at various places in the sliding ground.

The necessity for an improvement of the drainage of the sliding land district was early recognized, and, before the beginning of the autumnal rains in 1895, by permission of the property owners, a drain was dug through the southern rim of the basin or marshy ground at the head of the slide, so as to convey away any surface water which might otherwise accumulate there during the winter. That water had accumulated there formerly has been testified to by those familiar with the locality, but probably the depth did not exceed 2 ft. Hand-auger borings were also made in the marsh, and showed that the peaty formation on the surface did not exceed a depth of 20 ft. and was underlaid by a bed of clay.

While this work was in progress the King Real Estate Association was besought for permission to fill the pool in the depression left by them west of the cable railway embankment at the time the grading

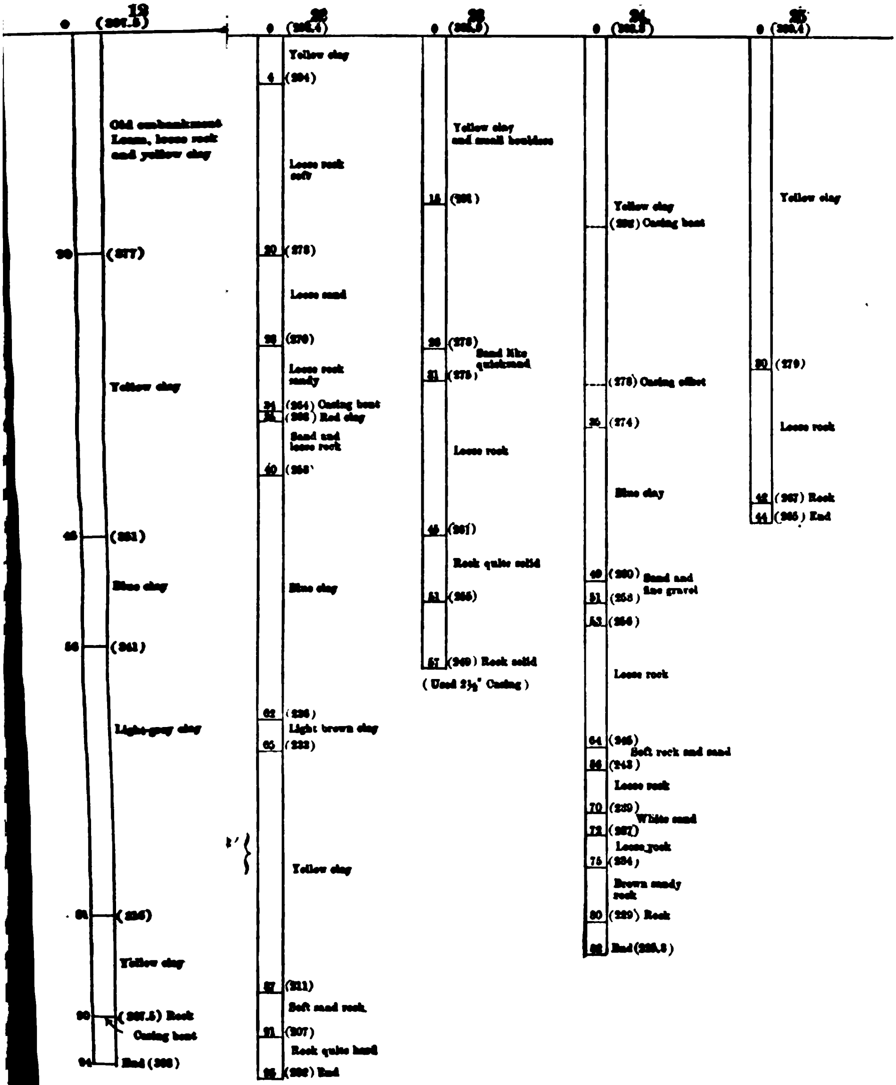
was done and the culvert built. This culvert or sewer was not laid deep enough to drain the bottom of the ravine, and, in consequence, a pool of water, 30 to 40 ft. in diameter, and from 3 to 5 ft. deep at the center, had accumulated there. This pool was kept full constantly by the drainage from several small springs which came to the surface in the bottom of the ravine above the railway crossing. The request of the chief engineer for permission to fill this pool, at the expense of the Water Committee, was granted by the property owners, after some little time had been taken to consider the matter, and the work was begun at once. Drains for the removal of surface water at points adjoining the reservoirs on the west were also built and connected with the sewers constructed during the previous year.

During the winter of 1895-96, and, in fact, during the entire year of 1896, the only construction work done in connection with the sliding land was to see that all ditches and drains were kept open so as to carry away all surface drainage. Surveys of the range lines were also made regularly each month to determine the rate of the movement. As one result of these repeated observations, it was noted that there was a marked increase during the winter or rainy months—say, November to May, inclusive—and a corresponding diminution of the movement during the remaining months of the year, when the rainfall was considerably less.

During 1896, the cracks in the reservoir linings were observed to be increasing slowly in number and size, and, for the purpose of determining what effect, if any, would be produced thereby, the water in the reservoirs was drawn down and at times the basins were entirely emptied. Owing to the cracked and broken concrete lining, and the absence of water in the basins, the reservoirs soon began to present an unsightly appearance.

It may be well to explain here that the quantity and quality of the water delivered to the city has never been affected by the defective condition of the City Park reservoirs. The reservoir system, as designed and built, provides that the reception of water from the main conduit, and its distribution to the different parts of the city, should all be done through the medium of wrought-iron or steel tanks, one of which is located in the interior of the gate-house connected with each reservoir, and in which all mains are centered. The reservoir basins were intended for storage purposes only. In some instances the inflow

OF RESER


Yellow clay
Loose rock soft
Loose sand
Loose rock sandy
Casing bent
Red clay
Sand and loose rock
Blue clay
Light brown clay
Yellow clay
Soft sand rock
Rock quite hard
End
Old embankment Loam, loose rock and yellow clay
Yellow clay
Blue clay
Light-gray clay
Yellow clay
Rock
Casing bent
End
Yellow clay and small boulders
Sand like quicksand
Loose rock
Rock quite solid
Rock solid
(Used 2½" Casing)
Yellow clay
Casing bent
Casing offset
(274)
Blue clay
Sand and fine gravel
Loose rock
Soft rock and sand
Loose rock
White sand
Loose rock
Brown sandy rock
Rock
End
Yellow clay
(279)
Loose rock
Rock
End

and outflow are through the same pipe, hence a circulation of water through the reservoir cannot be maintained without overflow into the sewers. The total estimated capacity of the four reservoirs connected with the system is 66 000 000 galls., or four days' supply for the city.

The temperature of the water delivered in the city during the summer months is also appreciably cooler* when distributed through the gate-chambers direct than it is when stored in the reservoirs, even for a few hours, and hence is more satisfactory. From the foregoing statements, it will be seen that the delay in completing the reservoirs for use has in no way detracted from the general excellence of the water supply furnished to the city during the past nine years.

Early in the spring of 1897 the proof that water in the underground springs, fed by percolation from the surface, was a prime factor in producing the slide, if not the only originating cause, became so conclusive that, on April 27th, the writer addressed a letter to the chairman of the Water Committee, explaining at considerable length the discoveries thus far made, and the reasons for believing that the removal of the water by a thorough system of drainage would stop the slide. In this letter, reference was made to a drainage project and estimate of cost which had been prepared by the writer during the preceding year.

A few weeks later, action was taken by the Water Committee, looking to the engagement of a consulting engineer to examine the sliding ground and report on the best means for the cure of existing conditions, which happily resulted in securing the services of G. H. Mendell, M. Am. Soc. C. E., Colonel, Corps of Engineers, U. S. A. (since deceased), for the investigation of the problem.

Colonel Mendell examined the reservoirs first in July, 1897, and also at intervals thereafter, and at his direction certain additional surveys and explorations were undertaken which resulted in the discovery of a large number of interesting data regarding underground conditions, and the depth and cause of the slide.

In order to avoid all uncertainties regarding the character of the bed-rock and the overlying earth, Colonel Mendell approved of the suggestion that wells or shafts be excavated to bed-rock by hand, and be made 3½ x 3½ ft. in size, instead of the 4-in. borings used formerly. This method of procedure proved to be very successful, and, in the

*The temperature is from 55 to 62° Fahr.

main, was followed in all subsequent explorations, although at one time the boring machine was again used for a few weeks in order to expedite the work.

The excavation of the open shafts, although more expensive than the smaller drilled holes, was in every way more satisfactory, for it was then possible to determine the character of the bed-rock and the overlying material more satisfactorily than could have been done in any other way. Especially was this true of the seam of blue clay adjacent to the bed-rock, forming the bed of the "ancient slide," which has played such an important part in all later studies of the problem.

Work on these wells or shafts was begun on July 19th, 1897, and prosecuted almost continuously from that time until January 24th, 1899, a part of the time with two crews of men. An ordinary winch and bucket, worked by hand, was used for removing the excavated material. It was found necessary to use curbing, from the surface down, 2 x 8-in. fir plank, notched at the corners, being used for this purpose. Twenty-two shafts, in all, were excavated, having an aggregate depth of 1 497 ft., with 454 lin. ft. of tunnel connected with the same. While this work was in progress, nine additional borings, aggregating 677 lin. ft., were made for the purpose of expediting the work and in order to fill in certain areas where the character of the material was not known with sufficient accuracy and it was mainly desired to determine the depth of the earth overlying the bed-rock. The location of the shafts is shown on Plate IX, and in Fig. 3, which shows some profiles through the center of the slide. Sections of the shafts and borings are shown on Plate XI.

The shaft excavations and borings were made experimentally, the discoveries at one shaft awakening inquiry and suggesting investigations at another point, and so on until a much larger field was covered and more work done than was anticipated at first. A number of surprising developments resulted from this series of investigations, particularly as to the character of the material between the surface and bed-rock, and the existence of a well-defined seam of clay near bed-rock which gave ample evidence of being the bed of the slide. In certain localities an unexpectedly large quantity of water was found in connection with the clay seam lying upon or near the surface of the bed rock, and much attention was given to investigations of the

SKETCH AND PROFILES OF MOVING GROUND
WEST OF RESERVOIRS NOS. 3 AND 4 CITY PARK, PORTLAND, ORE.
SHOWING GENERAL CHARACTERISTICS OF THE MATERIAL BETWEEN THE SURFACE AND BED-ROCK,
AS DETERMINED BY BORINGS AND SHAFT EXCAVATIONS COMPLETED IN 1896.

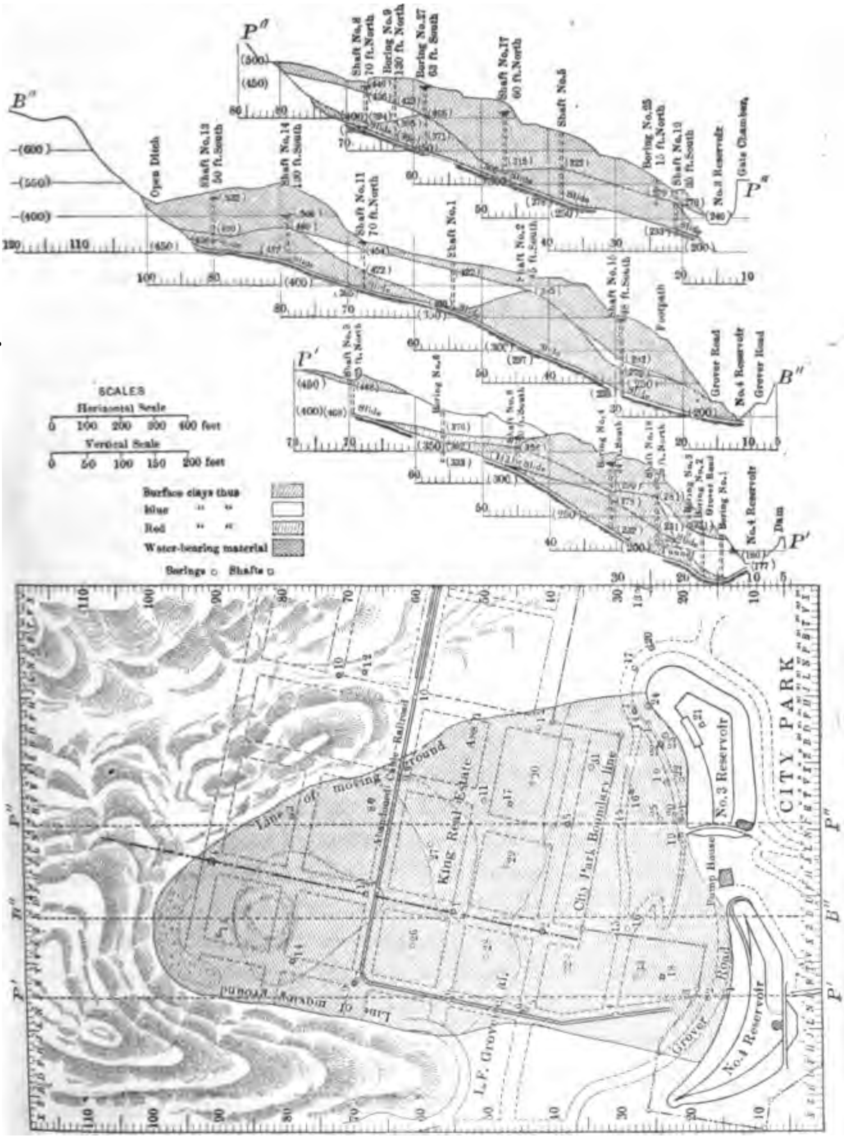


FIG. 8.

source and extent of this underground water supply, for by this time it had come to be fully realized that water in the seams of the material composing the hillside was, chiefly, the originating cause of the movement.

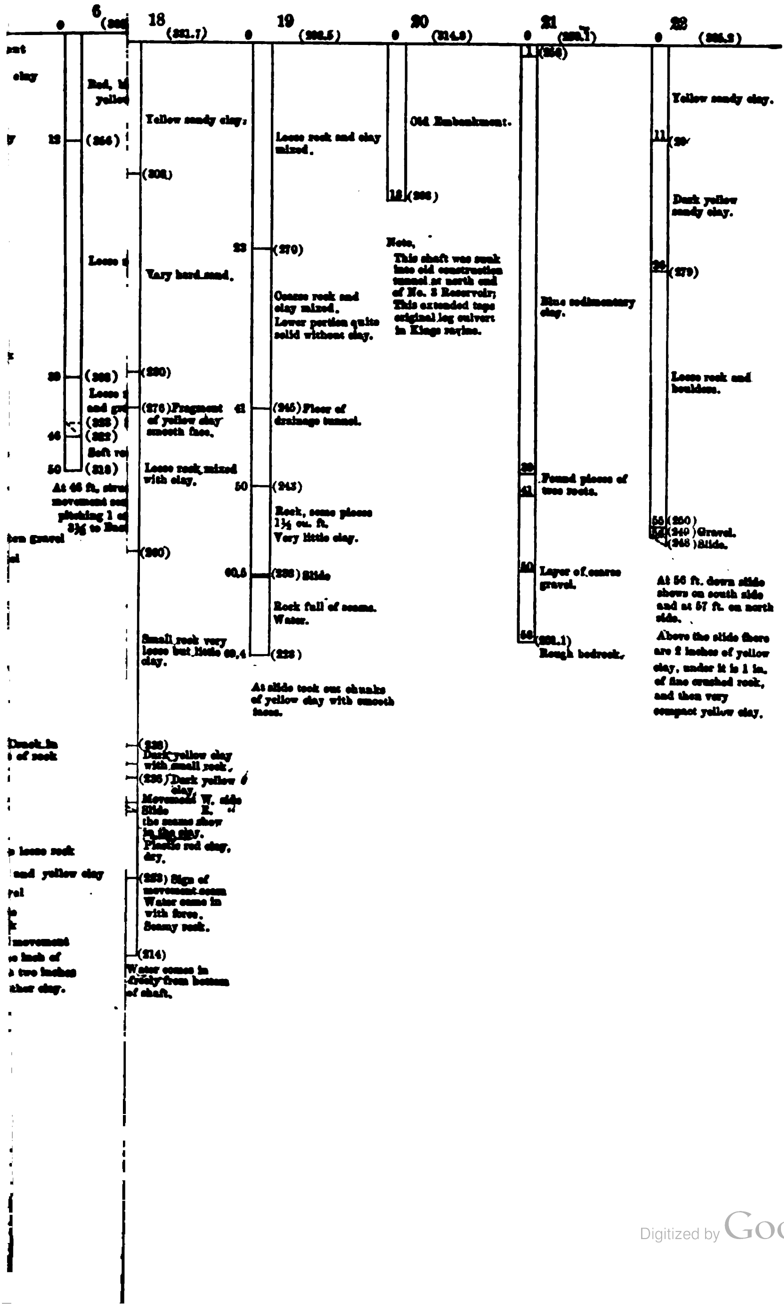
The first excavation made, Shaft No. 1, was on the line between the King and Carter claims, near the axis of the slide and about 900 ft. west from Reservoir No. 4, while Shaft No. 2 was about 250 ft. farther east. These shafts were located at these points simply because they would thus practically cover a large part of the territory adjacent to the reservoirs which remained unexplored at the conclusion of the work of the previous season. The discoveries made at these points were most surprising, and had an important bearing upon all the later investigations. A detailed statement of the peculiar characteristics of the material found in each shaft and boring will be found on Plate XI, but it may be of interest to refer briefly to some of the more important discoveries made.

Shaft No. 1.—The excavation of Shaft No. 1 was begun on July 19th, 1897, and completed on January 31st, 1898. The elevation of the surface was 435 ft. above the city datum in use in 1894, which was about the elevation of low water in the Willamette River. From the surface to a depth of 13 ft., a grayish quicksandy clay was found. It should be stated that the original surface of the ground had been removed when the streets and lots were graded and the consequent cutting down of ridges and filling of ravines was accomplished. The total depth of excavation was 75 ft.

At 13 ft. a hard, blue, sandy clay was found, upon the top of which a small quantity of water collected. At 25 ft. the blue clay was found mixed with fragments of rock, quite soft, and nearly disintegrated. At 26 ft. a crack, ½ in. wide, was noticed, having a northeast and southwest course, but it was soon lost. The ground at that depth was quite solid. The blue clay, mixed with rock, continued to a depth of 43 ft., where was found a blue, sedimentary clay without any admixture of broken rock. At this depth some small fragments of wood were found, which were apparently of fir. They were much discolored, but well preserved, the grain of the wood showing distinctly. The pieces of wood found in the shaft aggregated about ½ cu. ft. in volume. This blue, sedimentary clay continued, practically unchanged, to a farther depth of 15 ft., or to 58 ft. below the surface. At 50 ft.

PLATE XI.
PAPERS, AM. SOC. C. E.
MARCH, 1904.
CLARKE ON A PHENOMENAL LAND SLIDE.

S SUNK



foul air was encountered, making it necessary to put in a ventilating shaft, which consisted of a small box in one corner of the shaft, at the lower end of which a small fire was maintained. A few feet below this level a thin layer of material, very black, tough and dry, was found. At 58 ft. was found a mixture of blue and yellow clay, mingled with broken rock in which a water-worn or well rounded stone, 2½ ins. in diameter, was found. Until this stratum of clay and rock had been penetrated 10 ft., or to a depth of 68 ft. below the surface, little difficulty was caused by ground-water, which collected in the shaft only at the rate of from 25 to 40 galls. per day. At 68 ft., the clay at the west side of the shaft was dark blue, unmixed with rock, some pieces of clay having smooth faces. At this depth the flow of water increased suddenly, so that the shaft was filled to a depth of 18 ft. in one night. The next day the water was bailed out, and excavation was continued. During the following night the shaft was filled again, this time to a depth of 20 ft., the flow being at the rate of 1.8 galls. per minute. After contending with this flow of water for several hours, the shaft was deepened an additional foot, or to 69 ft. below the surface, more pieces of clay being found with smooth upper faces. At 6 P. M. on August 6th, 1897, just as the men were quitting work for the night, the flow of water increased suddenly to 40 galls. per minute, rising in the shaft 33 ft. in one hour. The next morning it stood within 8½ ft. of the surface of the ground, making a total rise of 60½ ft. in 12 hours.

The flow of water in the shaft was so strong as to render hopeless the task of lowering it with an ordinary windlass and bucket, and, therefore, it was decided to install a deep-well pump, run by steam power, in order to drain the shaft sufficiently to proceed with the excavation. This was done at once, and the pumps were in operation on August 19th, but at that time there was but little appreciation of the magnitude of the task, for it was not until January 31st that the work was completed and the pumps removed.

Beginning with two small pumps, with about 3½ x 18-in. cylinders, the number of pumps was increased to four before any appreciable headway could be made. The estimated capacity of all four pumps was 58 galls. per minute. By using four pumps it was practicable to lower the water nearly to the bottom of the shaft without continuous pumping, but, by resting half an hour, the water would rise in the

shaft, and pumping had to be resumed. By noting the diminishing height to which the water rose during the half-hour interval of rest, some idea was obtained as to the progress which was being made in draining the underground reservoir. At first, the water would rise from 14 to 15 ft. in half an hour, while toward the end the rise was not more than one-quarter of that amount in the same time. During a portion of the time, in order to expedite the work, the pumps were run day and night.

Toward the latter part of January, 1898, the flow diminished to such an extent that it was practicable to dispense with two of the pumps, thus giving room to work in the bottom of the shaft while pumping was in progress. After an effort lasting several days, the layer of loose rock, underlying the clay seam heretofore mentioned, was penetrated, and, at a depth of 75 ft., bed-rock was reached and found to be comparatively smooth and free from fissures. Above the bed-rock, at the east side of the shaft, a plainly defined movement seam was uncovered, having 5 ins. of dark blue clay above the line of cleavage, with fine broken rock between the clay and the solid bed-rock. The inclination of the clay seam was eastward, approximately 2.5 ft. in the width of the shaft.

The line of cleavage in the stratum of clay was defined very clearly. The upper and lower portions of the stratum could be easily separated along the line of cleavage, and the faces which had been in contact presented uniformly a smooth and glazed appearance. When first exposed, the surfaces were bright and shining, as though they had been varnished, but when dry the color was of a dull and leaden hue. There were slight ridges or inequalities in the surfaces, running east and west, showing the presence of grains of rock or some hard substance, and indicating also that movement had been taking place along the plane of the two surfaces. The excavation was carried below the main water-bearing stratum, which appeared to be above the clay seam.

On January 31st, 1898, after the excavation had been carried to bed-rock, the pumping was discontinued. The total quantity of water pumped from the shaft from August 19th, 1897, to January 31st, 1898, was, approximately, 3 925 000 galls.

Measurements made on February 16th, 1898, showed that the water level in the shaft had been lowered 51 ft. by the removal of

nearly 4 000 000 galls. of water. After the cessation of pumping, the water continued to rise slowly until March 2d, 1899, when it stood at Elevation (435), or level with the surface of the ground. It was afterward noted that there was a slight falling away during the dry season, followed by a complete recovery during the winter.

The view shown in Fig. 8, Plate VI, was taken on September 28th, 1897, looking north from the summit of the ridge near the old ball ground south of the reservoirs. On the right can be seen the dam, gate-house and about half of Reservoir No. 4, and also the power-house and the gate-house and principal part of Reservoir No. 3. To the west of the power-house and Reservoir No. 4 is shown the roadway and the rip-rapped slope above it, and beyond, and farther to the left, is the small grove at the southwest corner of the City Park. Still farther west can be seen the terraced ground, with the temporary pump-shed at Shaft No. 1 standing near the center.

Shaft No. 2.—While the work on Shaft No. 1 was in progress, the other shafts were also being excavated. Shaft No. 2, one block east of Shaft No. 1, and also on the line between the King and Grover claims, the surface elevation being (408), was begun on July 19th, and completed on August 20th, 1897. The total depth of the shaft was 112 ft.

The same grayish, quicksandy material found near the surface of Shaft No. 1 was found here to a depth of 17 ft., and below that a stratum of yellowish sand, 6 ft. thick. At 12 ft. below the surface, a vertical crack, ½ in. wide, running northeast and southwest, was noticed, the material west of the crack being yellow, while that on the east side was of a bluish color. The excavation followed the crack for about 7 ft. only. From 23 to 45 ft. the material was principally very hard sand. From 45 to 53 ft. yellowish clay mixed with broken rock was found. From 53 to 71 ft. the material was principally sand, similar to that between 23 and 45 ft., and, in places, was very hard to pick. From 71 to 105 ft., grayish, honeycombed rock, full of seams, with some earth, was found. In some places the material was hard, and in other places it could be picked easily. At 105 ft. the material was quite loose, with some pieces of dark blue clay. Here 20 galls. of water collected in one hour. From 105 to 110 ft. small stones mixed with coarse sand were found. At 112 ft., solid rock, free from seams, was found, with a dip to the east of about 1 on

3.5. There was a stratum of dark blue clay 1 ft. thick on top of the rock. The line of the slide was defined clearly near the bottom of the clay. Since the completion of this shaft the water has never collected to a greater depth than 7.5 ft.

Shaft No. 3.—In excavating Shaft No. 1 it was noticed that the water at the bottom of the shaft came from the northwest, which fact called renewed attention to the springs in that direction and west of the old "pool," to which reference has already been made. It was therefore decided to sink Shaft No. 3 near the west end of the ravine in which these springs were situated.

The elevation of the surface was (467.5). The depth of the excavation was 10 ft. Excavation was begun on August 9th, 1897, and abandoned the next day, as the location was found to be too near the margin of the moving ground to afford the information desired.

For the first 6 ft. yellowish clay and logs were found intermingled. A small quantity of water came from seams in the rock at the north end of the pit. When work was suspended, the materials found were clay at the south end of the pit and loose rock at the north end.

In regard to the springs, the owner of the property stated that the flow of water was much less than when he first examined the ground, perhaps forty years ago, the springs formerly furnishing a water supply for some of the buildings on the eastern border of the property.

Shaft No. 4.—The point next selected for examination was a few feet north of the claim line and a short distance from the western end of the moving ground, the surface elevation being (530.5). The depth of the excavation was 73 ft. Excavation was begun on August 11th and completed on August 23d, 1897.

From the surface down for a depth of 6 ft., the material was yellow clay, and below that was found 19 ft. of bluish clay. From 25 to 43 ft., were found gray and yellow clays which were quicksandy in places. From 43 to 72 ft., the material was chiefly red clay mixed with small pieces of porous rock. Between 44 and 46 ft. the clay was very plastic and was yellow when dry. At this level, 150 galls. of water collected in one night. From 72 to 73 ft., a layer of dark blue clay resting upon rock was found. The surface of the rock could be picked to the depth of 6 ins., but below this it was hard. The rock dipped slightly to the east. The line of the movement seam was defined clearly between the depths, 72 and 73 ft., and consisted of about 1 in. of red or yellow clay resting upon blue clay, with solid rock underneath.

This shaft being near the border of the moving ground, it was next determined to run a tunnel along bed-rock until the northern limit of the slide should be reached, if this could be found within a reasonable distance. The slope of the rock being easterly, the tunnel was started in a northwesterly direction, in order to provide for drainage. This work was begun on August 26th and completed on September 15th, 1897. The securing of proper ventilation for the shaft and tunnel proved to be quite a hindrance. As the tunnel was expected to be only a temporary affair, it was made as small as could be worked conveniently, about 3 x 5 ft., and was not timbered thoroughly. The material encountered was similar to that in the shaft, being chiefly reddish clay mixed with fragments of porous rock. The tunnel followed the top of the stratum of blue clay; the dividing line between the blue clay and the red clay and gravel being plainly marked.

At 28 ft. from the shaft was found a seam of blue clay, 1 in. thick, with smooth faces, showing pressure, but not furrowed. The dip of the seam was 3 ins. in 2 ft., and to the northeast. At 32 ft. a plainly defined crack was found which was nearly vertical and crossed the tunnel nearly parallel with the break in the surface of the ground, which marked the margin of the slide opposite that point. When approaching this crack the breast of the tunnel fell in, showing the line of the movement seam. Beyond the crack, the material was cemented and much harder than anything found before, some large pieces of rock appearing in the face. From measurements made at the tunnel level, and also at the surface of the ground, the slope of the run of the slide at that point was determined as approximately 9¼ vertical to 1 horizontal.

During the excavation of the shaft and tunnel, the water draining from the ground caused little trouble until a point near the bottom was reached. The quantity which collected each night gradually increased from 8 galls., when at a depth of 25 ft., to 120 galls., when at the bottom, with the exception of one night, already noted, when, at a depth of 44 ft., the quantity collected was 150 galls. The drainage was principally from the north. After the completion of the tunnel, the water collected for some days at the rate of 20 to 25 galls. per hour, and in about two weeks it had filled the tunnel and shaft to the depth of 17.5 ft. In February, 1898, the water stood at Elevation (514.9) or at a depth of 56.4 ft., but the ordinary depth was from 25 to 40 ft.

During the period covered by the observations the variations in the water level at this shaft were much more marked than at any other point observed. The rise which took place within a day or two after a heavy rainfall was especially noticeable. As a possible explanation of this sudden rise, it may be noticed that the shaft is at the foot of a steep bank where the coating of fine surface earth is comparatively thin and the underlying material probably more than usually porous. The tunnel, having a direct connection with the crack reaching to the surface, may also have had some effect. It may be noted, also, that at this point, and at all other shafts, the surface around the opening was protected against direct drainage into the well.

Shaft No. 5.—Work at this point, located about 400 ft. west of Dam No. 3, was begun on August 23d and completed on September 21st, 1897. The surface elevation was 379.6. The depth of the excavation was 101.4 ft. For the first 6 ft. the excavation was through an old embankment made when the property was being graded. Next was found 11 ft. of yellow surface earth and below that 40 ft. of grayish, porous rock, growing harder toward the bottom, where it was full of seams, and similar to that found in Shaft No. 2 at about the same elevation. Next below, a 2-ft. layer of small stones and coarse sand, cemented, was found, followed by 6 ft. of hard basalt in small pieces, which could be removed with a pick. Below that, for a further distance of 30 ft., rock of the same general character continued. The fragments of rock were mostly small (one layer, several feet in thickness, consisting of pieces of rock ½ in. to 2 ins. in diameter and so loose as to require the use of curbing), except near the bottom, where larger blocks were found, some of which had to be broken before they could be removed from the shaft. Below the larger pieces of rock came 3 ft. of yellow clay mixed with small fragments of rock, and then came another layer, of about the same thickness, of very loose material, consisting chiefly of fragments of rock 1 in. in diameter and smaller, with sand and clay, upon the bottom of which was a facing of about 1 in. of blue clay, the under face of which was smooth. Next came 6 ins. of mixed clay and rock fragments, below which bed-rock was found, smooth and without fissures. The total thickness of the distinctly clay seam was about 3 ins., through which a line of cleavage, indicating the movement plane, was defined clearly. The dip of the bed-rock was to the northeast, and about 1 on 4.5.

The depth below the surface was 101.4 ft., equal to Elevation (278.2).

Only a small quantity of water collected in this shaft at any time during the progress of the work, and at no time since the excavation was completed has there been in the shaft a greater depth of water than 8.5 ft., with only slight fluctuations between summer and winter.

Shaft No. 6.—The next shaft undertaken was No. 6, located near the cable track, alongside of Boring No. 5 made in 1895, and about 230 ft. south of Shaft No. 2. The elevation of the surface of the ground was (368.5), and the depth of the excavation 50 ft. The work was begun on September 17th and completed on September 29th, 1897.

For the first 12 ft. the material was a mixture of clay and fragments of basalt nearly decomposed. Then, for 27 ft., the material was found to be darker in color and harder. As a rule, the fragments of rock were small, although some pieces measured about 1 cu. ft. in volume. Next was found 7 ft. of small fragments mixed with clay, reaching a depth of 46 ft., at which point, Elevation (322.5), a seam of blue clay, a few inches thick, was found, which showed a distinct line of cleavage. The dip of the seam was eastward, 1 on 3.5. There were pebbles within 1 in. of the face of the seam, above and below. The rock below the clay seam was quite soft but, as the excavation proceeded, rapidly grew harder, until at the depth of 4 ft. below the clay, or 50 ft. from the surface, Elevation (318.5), it became too hard to excavate without blasting, and work was discontinued.

There was some difficulty with the ventilation of this shaft, but the water caused no inconvenience whatever. At one point, near the bottom, about 40 galls. of water accumulated during one night. At no time since the shaft was completed has the water exceeded a depth of 9.5 ft., and, during the summer, the shaft is practically dry.

As has been stated, this shaft was beside Boring No. 5, the curbing for the shaft enclosing the pipe casing. As the excavation of the shaft proceeded, it became necessary to remove the pipe, which was found to have been broken near the bottom. Later, the elevation of this break was found to be (323.8), or 1.3. ft. above the clay stratum along which the movement was taking place. By the rod measurements made from the surface, as heretofore described, it had been

determined some months before that the break in the pipe and the bottom of the slide were at Elevation (324.5), or 0.7 ft. above the point where the break actually occurred and 2 ft. above the movement seam in the clay. The measurements in the shaft thus furnished a good check on the former work.

By measurements made at this shaft, it was also determined that the rate of movement at the surface and at bed-rock level had been practically the same. When Boring No. 5 was made, in 1895, the drill was broken at a depth of 47.6 ft. After spending some time fishing for the broken tool, the work was abandoned as the engineers were then quite confident that bed-rock had been reached. Later, when Shaft No. 6 was excavated, the pipe put in as a casing for Boring No. 5 was uncovered, and the foot of the pipe was found to be about 2 ft. east of the point where the broken drill was still standing. This distance, 2 ft., corresponded almost exactly with the eastward movement which the surveys showed had taken place at the surface of the ground during the same period. After completing the shaft, a range line was established crossing it from south to north; and points set both at the surface and at the bottom of the well. Subsequent observations of this range line showed that between October 25th, 1897, and November 22d, 1899, the total surface movement was 0.49 ft. to the eastward, while the movement at the bottom of the shaft was 0.47 ft. during the same period, a difference of only 0.02 ft.

Shaft No. 7.—Shaft No. 7 is on the roadway, a short distance west of the retaining wall at the north end of Reservoir No. 3, and alongside of Boring No. 14 *C*. The elevation of the surface was (311), and the depth of the shaft 53.5 ft.

Work was begun on September 21st, and continued until October 1st, 1897. Work was resumed on April 15th, and continued at intervals until December 25th, 1898. The total depth reached was, as stated, 53.5 ft., equal to Elevation (257.5). To make further explorations of the line of the slide, two tunnels were run in a southerly direction, one at Elevation (287) and the other from the bottom of the main shaft, Elevation (257.5). In the shaft and also in the tunnels the line of the movement seam was uncovered. In the first 14 to 15 ft. from the surface the material consisted chiefly of yellow clay containing broken rock. Next came a seam of plastic yellow clay, very tough, having a southerly inclination of about 1 on 1.3. The casing

of Boring No. 14 *C* was found broken at Elevation (296.8), or within 0 2 ft. of the clay seam at the west side of the shaft. The upper portion of the pipe had moved 0.7 ft. eastward, plainly indicating the depth at which the movement of the slide was taking place. Below the yellow clay was 27 ft. of blue, sandy clay, which was very hard when dry, as was the case in this shaft, but which, when immersed in water, would soon dissolve. Below the blue clay came about 1 ft. of tough, yellow clay, similar to that found on top of the blue clay, and having about the same southerly inclination. The depth from the surface was 43 ft. Next below, loose rock was found, with a small quantity of clay mixed, into which the shaft was carried 10.5 ft. to Elevation (257.5).

The direction of the tunnels was nearly parallel with the west line of the City Park. The upper one, at Elevation (287), cut the movement seam between the red and blue clay at 6.4 ft. from the south edge of the shaft, and entered the reddish clay mixed with loose rock, in which it continued for 70 ft., at which point the work was abandoned. In the lower tunnel, the movement seam was found in a stratum of plastic yellow clay from 1 to 1.5 ft. thick, and 52.5 ft. from the shaft. This tunnel was continued for a distance of 74 ft. The material was loose rock mixed with a small proportion of clay. The southerly dip of the movement seam passed below the tunnel level, and, in order to develop it still further, a pit was started below the bottom at a point 64 ft. from the shaft. At a depth of 8.7 ft., or Elevation (248.8), fragments of red clay on top of yellow clay were found having smooth faces, indicating the line of the slide, but the flow of water from the crevices in the loose rock was so strong that it caused the abandonment of the work at that depth. The water rose in the pit 6 ft. in one hour, but at no time did it reach the tunnel level.

Shaft No 8.—This shaft is a few feet from the margin of the old "pool," west of the cable track, and near the upper end of the sewer put in to drain the pool and adjacent ravine. The elevation of the surface was (446.4), and the depth of the excavation 63 ft. The work was begun on October 4th and completed on October 16th, 1897. The tunnel excavation was made between November 12th and December 1st, 1897. For the first 10 ft. from the surface, the excavation was through filled ground, below which came 18 ft. of blue clay containing a liberal mixture of fine sand. Next came 19 ft. of material of the same

character, and, in addition, water, which flowed at the rate of 30 galls. per hour. In places the walls of the shaft caved badly, owing to the quicksandy nature of the material; and, until the excavation had passed into more stable ground, a night crew kept the shaft pumped out and the walls dry, so as to prevent caving. Below the depth of 35 ft. there was no difficulty from this source, the material being much harder and the walls not as easily affected by the water, which still continued to percolate through the ground and into the shaft.

Between the depths of 47 to 52 ft. there was found a stratum of tough, dark blue clay mixed with small fragments of hard basalt. Below the blue clay came a 10-ft. layer of tough, plastic yellow clay, with little or no rock intermixed. At the bottom of the yellow clay, at a depth of 62.7 ft., Elevation (383.7), and just above bed-rock, there was found about 2 ins. of dark blue clay, not as plastic as the yellow, upon the top of which, between the yellow and the blue, the line of cleavage which indicated the plane of the movement could be discerned. The bed-rock dipped about 1 in 4.5 to the eastward.

From the foot of the shaft a tunnel was started in a northwesterly direction, for the purpose of developing the northern margin of the sliding land. The material in the tunnel proved to be mostly yellow clay, which was quite hard. At a distance of 22.3 ft. the tunnel cut the movement seam, which was nearly vertical. A few feet further on, large masses of rock were found, cemented and appearing to be in place, beyond which the excavation was not carried. From measurements made at the level of the tunnel, and on the surface, the inclination of the northern rim of the slide at this point was found to be 1 vertical on 0.6 horizontal.

During the last part of the work on the tunnel water collected at the rate of 50 galls. per hour. Within one week after the tunnel was completed, the water in the shaft had reached a depth of 6 ft., and, later, a depth of from 9 to 10 ft., maintaining that height, with little fluctuation, until the final draining of the shaft in 1900.

Shaft No. 9.—This shaft was started but a few feet from Boring No. 7, near the point where the cable road first touches Kingston Avenue and turns to the north along that street. The surface elevation was (460.8) and the depth 55.5 ft. Work on this shaft was begun on October 19th and completed on November 3d, 1897.

For the first 13 ft. the excavation was in yellow sandy earth. Next

came 19 ft. of blue clay with fine sand, quite quicksandy. Some difficulty was caused by the caving of the walls of the shaft. At this time the drainage from the sides of the shaft was about 30 galls. per day. For the next 21 ft. the blue clay was dryer and tougher, with less sand, and was difficult to handle. Before reaching bed-rock, at 53 ft. depth, Elevation (408), a stratum of from 6 to 8 ins. of plastic blue clay was met, in which the line of cleavage was found within 1 in. of the bottom. The movement had been taking place along this line. The slope of the seam was 1 in 2.2 to the eastward. Below the slide, the surface of the rock was decomposed and full of seams to a depth of 2.5 ft., and could be removed with a pick. At 55.5 ft., or Elevation (405.3), the rock became much harder, and work was suspended.

After passing below the slide, the quantity of water increased rapidly, coming in through the fine seams in the rock, more coming from the southwest than from elsewhere. The quantity removed before the shaft excavation was completed averaged more than 400 galls. per day.

Shafts Nos. 10 and 12.--The surface of Shaft No. 10 was at Elevation (445.8), and its depth was 22.5 ft. The surface of Shaft No. 12 was at Elevation (442.2), and its depth was 25.5 ft. To provide an adequate system of surface drainage for the water-shed of King ravine, which borders the sliding land on the north, the consulting engineer recommended the construction of a culvert to extend from the 24-in sewer near Reservoir No. 3 westward to some point west of the cable railway, where the subterranean flow, also, could be cut off and be brought to the surface, and into the culvert.

In pursuance of this plan, Shafts Nos. 10 and 12 were excavated in the bed of this ravine, a short distance west of Kingston Avenue, for the purpose of determining the nature of the material near the upper end of the proposed culvert. By these excavations it was ascertained that the bed of the ravine, for several hundred feet west of the bridge, was composed of a mass of loose rock, mostly of large size, with gravel and sand intermingled and covering the same, through the interstices of which the water which found its way under the surface quickly disappeared. As an outcome of these explorations, it was necessary to extend the culvert several hundred feet further west than was intended originally, so as to reach a point where the rock came near to the surface.

Shaft No. 11.—When Boring No. 8 was completed, in December, 1895, the drill passed through a body of blue clay, very wet and nearly 50 ft. in depth, and soon after it was found that the inside of the pipe was filling with "blue mud." The reason for this could not be ascertained at the time, but the action was thought to be due either to a crack in the casing or to the fact that the pipe had not been driven sufficiently to make a close joint with bed-rock, thus allowing the mud and water to enter the pipe at the bottom. To gain further information regarding this deposit of quicksandy material, it was decided to sink a shaft near the boring formerly made. The location chosen finally for Shaft No. 11 was just west of the cable track, and also on the claim line, and about 40 ft. southwest from Boring No. 8. The depth of the shaft was 51 ft., and the surface Elevation (462.9). The excavation of this shaft was in progress from November 5th to 10th, and from December 2d to 8th, 1897, when a sudden inflow of water caused a suspension of the work.

For 9 ft. below the surface the material consisted of the usual clayey earth, and then came 32 ft. of blue clay similar to that found in Shaft No. 9, which was about 300 ft. to the south. Between the depths of 25 and 35 ft. the material was very soft, water collecting at the rate of 15 galls. per hour. At 41 ft. the material changed to loose rock mixed with clay, which continued for a depth of 9 ft., or to a point 50 ft. below the surface. During some nights 400 galls. of water collected. The upper surface of this stratum of loose rock and clay dipped to the north and east about 2 vertical to 1 horizontal. Between 50 and 51 ft., below which depth the excavation was not carried, the material became quite loose, and was shoveled easily. It consisted chiefly of coarse sand and loose rock, $\frac{3}{4}$ in. to 2 ins. in diameter. When work was suspended, on the evening of December 7th, the excavation had been carried into this loose material to a depth of 1 ft.

On the morning of the 8th, water was found standing in the shaft at a depth of 46.5 ft., or within 4.4 ft. of the surface of the ground. Immediately following the inflow, several attempts were made to bail out the water by hand, but all were unsuccessful. One trial of hand bailing was made between January 10th and 24th, 1898, when the removal of 77 000 galls. lowered the water level only 2.1 ft. Bailing having failed, it was next determined to try the well-boring machine

for the purpose of ascertaining the depth to bed-rock. Work with this machine was begun on March 9th and completed on March 11th, 1898, and resulted in finding hard rock 17 ft. below the bottom of the shaft already excavated (or 68 ft. below the surface), the drill passing through loose rock for the entire 17 ft. The elevation of bed-rock was (395).

To test still further the volume of water in the underground reservoir connected with this shaft, operations were begun on October 17th, 1898, with the steam pumps used formerly at Shaft No. 1, and pumping was continued with regularity until November 30th. While pumping was in progress the water level was lowered somewhat, but it was found that a very slight impression was being made upon the body of water connected with the shaft. The first hour after pumping ceased the water in the shaft rose 10 ft., and measurements made a few days later showed that the water level had been lowered 6.1 ft. The estimated volume pumped was 546 700 galls. Finding that constant pumping for six weeks had lowered the water level only 6.1 ft., or less than one-seventh of the total depth, it was decided to abandon further attempts to drain the shaft by such methods. During the following winter the water stood at Elevation (458.9), or about 4 ft. below the surface of the ground.

Shaft No. 13.—This shaft was begun near the head of the slide and about 200 ft. south of Shaft No. 4. The elevation of the surface was (531.9). Work was begun on December 18th, 1897, and completed on January 6th, 1898. The depth of the shaft was 81.4 ft.

For the first 12 ft. yellow surface earth was found. Between 2 and 10 ft. a vertical crack was noticed, having a course northeast and southwest. Next, 5 ft. of blue quicksandy clay was found, followed by 15 ft. of yellow quicksandy clay in which water collected at the rate of from 20 to 40 galls. per hour. The next stratum was 20 ft. of yellow clay without sand, below which was one of 11 ft. of tough red clay, hard to work. The inflow of water was about 10 galls. per hour. The stratum of red clay was underlaid by 12 ft. of a mixture of yellow clay and broken stone, some of the clay being quite soft. From 20 to 60 galls. of water collected per hour, most of it coming from points within 20 ft. of the surface. At a depth of 73 ft. a seam in the clay was discovered, dipping to the south, about 1 on 2, and at 75.5 ft. the main slide was uncovered, with yellow clay on top of from 6 to 10 ins.

of hard blue clay. The slope was 1 on 3.5, with a slight descent to the eastward. Below the movement seam loose rock was found, which, at a depth of 81.4 ft., was too hard to pick, so that the work was abandoned. The water collected in the shaft at the rate 8 galls. per hour, and during the winter of 1898–99, it stood at a depth of 74 ft.

Shaft No. 14.—This shaft is on the south side of the "round top" and about 200 ft. west of the cable track at Shaft No. 9. The surface elevation was (506.1), and the depth of the excavation 69.3 ft. Excavation was begun on January 31st and completed on February 26th, 1898.

Below the surface, a stratum of yellowish clayey earth, 8 ft. thick, was found, followed by 11 ft. of very tough red clay. Below the red clay was found broken rock, decomposed considerably on top, but growing harder gradually as the depth increased, and having many vertical seams. For a depth of 33 ft. the fragments of rock were mostly small, some being ½ cu. ft. in volume. Below this was a 2-ft. stratum of harder rock, the blocks being about 1 cu. ft. in volume. For the next 10 ft. the fragments were smaller, and then came 5 ft. of very fine rock, mixed with coarse sand. Below this was a stratum of clay, about 4 ins. thick, resting upon bed-rock. The usual line of cleavage in the clay was found in this instance within ½ in. of bed-rock. The slope of the bed-rock and movement seam to the southeast was about 5 ins. in 3.5 ft. horizontal.

After first penetrating the loose rock, water came in freely from all sides, but the flow was strongest from the south and east. Constant pumping was required to keep the shaft clear so that the work could proceed. The pumps were kept manned for two nights in order to finish the work. Pumping was suspended on February 26th, and in 40 hours thereafter the water in the shaft was 26 ft. deep.

Shaft No. 15.—This shaft is on the bank, about 300 ft. west of the power-house, and by the side of Boring No. 16. It was first thought that Boring No. 16 had reached bed-rock; later, when it was noticed that no bending of the pipe occurred while the surface continued to move, it was decided to sink a shaft at this point. The excavation was begun on February 28th, and completed on April 9th, 1898. The surface elevation was (347.5), and the depth of the excavation 115 ft.

Next below the surface was found a stratum of 33 ft. of yellowish sandy material, followed by 14 ft. of plastic yellow clay. Next was

found 17 ft. of tough yellow clay mixed with fragments of decomposed basalt, and below this 11 ft. of loose rock honeycombed and with a small mixture of clay, Elevation (272). For the next 16 ft. the material was of a character similar to that immediately above, with some variation in the hardness and size of the fragments of broken rock. Between the depths of 93 and 107 ft. there was found a stratum of fine broken rock varying from ¼ to 1 in. in size, and very easily picked. From 107 to 108 ft. the fragments of rock were larger, being 2 cu. ins. in volume, and the rock was very compact and hard to pick. From 108 to 109 ft. there was some clay, mixed with broken rock. At 109 ft., or Elevation (238), was found a seam in the clay showing movement, a thin layer of blue clay resting on tough red clay. At 114 ft., or Elevation (233), bed-rock was found at the west side of the shaft, with a slope to the northeast of 1 on 3. There was mixed material on the bed-rock to a depth of 1 ft. The upper 6 ins. was dark blue clay with some small stones, while the bottom 6 ins. was plastic clay, lighter in color. A plainly defined line of movement, within 2 ins. of bed-rock, was observed. At 59 ft. from the surface was found a crevice, 7 ins. wide, filled with loose material, and at this point water collected at the rate of about 30 galls. per hour. At 75 ft. the bottom of the casing for Boring No. 16 was found resting on top of a large boulder, the pipe being only about 6 ins. out of plumb. At this point the material was loose, and all water which dripped into the shaft soaked away.

The material at the bottom of the shaft, below Elevation (240), was water-tight, and, while the last of the excavation was being made, the water rose in the shaft at the rate of 4 ft. per hour. It was only after bailing and pumping for some days that the flow diminished sufficiently to permit uncovering the bed-rock.

Shaft No. 16.—The point selected for Shaft No. 16 was opposite the south end of Reservoir No. 3, and only a few feet from the west boundary of the Park. The surface elevation was (331.7), and the depth of the shaft was 97 ft. Excavation was begun on April 9th, and completed on May 17th, 1898.

For 31 ft. from the surface, the excavation was in yellowish surface clay, a small quantity of water collecting each night. From 31 to 65 ft., Elevation (267), the material was fine broken rock, which it was necessary to pick; but it was found that the walls of the shaft would cave in unless they were supported. From 65 to 82 ft., Elevation (250),

seamy rock was found, which could be removed with a pick. Some water entered the shaft from the east. From 82 to 97 ft. the excavation was still in rock, and proceeded slowly. From 95.5 to 96.5 ft. fine loose rock was found. At 97 ft., or Elevation (235), a thin stratum of blue clay was found lying on yellow clay, with bed-rock underneath. The bed-rock was honeycombed, but there were no seams. The slope was 1 on 3.5 to the east and southeast. During the night 500 galls. of water collected, coming mostly from the northeast. There were indications of the clay movement seam, but, on account of the water, the usual sample showing the line of cleavage could not be obtained.

Shaft No. 17.—This shaft was excavated at a point about 360 ft. east from the cable track, and opposite the "pool." The excavation was begun on April 19th and completed on May 20th, 1898. The surface elevation was (407.6). The depth of the shaft was 103 ft. Next below the surface was found 8 ft. of old embankment, and below this 11 ft. of yellowish, sandy clay. The next stratum was 12 ft. of loose rock mixed with clay, below which was a stratum of 1 ft. of quite solid rock. Below this, from 32.5 to 93 ft., was found a stratum of small rock, from 1 in. to 4 ins. in diameter, mixed with yellow clay in about equal proportions. The elevation of the base of this stratum was (315). From 93 to 101 ft., Elevation (307), large blocks of stone, up to 2 ft. in diameter, were found, with little clay. From 101 to 102.3 ft., was found a layer of small fragments of rock ½ in. to 2 ins. in diameter. Between 102.3 and 103 ft., Elevation (304.6), a stratum of yellow clay on blue clay, resting on bed-rock was found. The slope was about 1 on 3 to the northeast. The movement seam was found between the yellow and the blue clay. A small quantity of water entered the shaft from the southwest.

Shaft No. 18.—Excavation for this shaft was begun on the face of the bank 210 ft. west of the west side of Reservoir No. 4, and opposite the point of greatest movement of the parapet walls. The surface elevation was (318), and the depth of the excavation 115.5 ft. Work was begun on May 18th, and the shaft and the tunnel connected with it were completed on December 16th, 1898. The following materials were found: From 0 to 15 ft., Elevation (303), yellow, sandy clay; from 15 to 38 ft., Elevation (280), very hard sand; from 38 to 80 ft., Elevation (238), loose rock, in small fragments, mixed with a small

quantity of clay. About midway in this mass there was a 2-ft. stratum of loose rock, 1 in. to 6 ins. in diameter, without clay, where the walls of the shaft tended to crumble and slide. At a depth of about 80 ft., Elevation (238), the excavation entered dark yellow or reddish clay mixed with small fragments of rock.

Movement seams, in red clay, were found at 86.5 ft., Elevation (231), at the west, and at 87.5 ft., Elevation (230), at the east, side of the shaft.

At 95 ft., Elevation (223), the excavation was still in plastic red clay, when, on June 7th, 1898, a fragment of clay, having a smooth face, was loosened in the bottom of the shaft, and water flowed from the cavity with considerable force, rising in the shaft to a height of 3 ft. in 15 minutes, so that a suspension of work was necessary. After several ineffectual attempts to lower the water by hand bailing, a steam pump was set up, and, by August 22d, the flow had diminished to such an extent as to admit of deepening the shaft (through loose material, coarse sand, and stones 6 ins. in diameter and less), to Elevation (214). On August 22d, 1898, pumping was suspended. The total volume of water removed from the shaft then amounted to more than 655 000 galls.

Later in the season, it was decided to run a branch from the old drainage tunnel behind Reservoir No. 4 to Shaft No. 18, to draw off the water which continued to collect at that point. This branch was started from the old tunnel in a bed of "blue clay," and, at 42.5 ft., passed into loose rock faced with about ½ in. of yellow clay, the line of movement showing between the blue and yellow clay. The dip to the east was 1 on 3. When within 10 ft. of Shaft No. 18, the flow of water was at the rate of 75 galls. per minute, but did not continue long at that rate. After reaching and draining the shaft, the excavation was deepened below the floor of the tunnel, or to Elevation (202), when the work was suspended. The material continued to be seamy rock, through which water flowed freely, coming from the west. The total length of the branch tunnel excavated was 131 ft.

Shaft No. 19.—The point selected for this shaft was 10 ft. west of the west end of Dam No. 3. The surface elevation was (292.5). The excavation was begun on June 8th and completed on July 30th, 1898. The depth of the shaft was 60.5 ft. From the surface to a depth of 50 ft., Elevation (292.5), the upper portion of the stratum was loose rock

with which some clay was mixed, the pieces of rock in the lower portion being from 1 in. to 6 ins. in diameter, and quite compact, without admixture of clay. At Elevation (245) the shaft intersected the bottom of the drainage tunnel excavated in 1895 along the western margin of Reservoir No. 3. The sewer pipe was found to have been cracked. From 50 to 60 ft., Elevation (232.5), the material was chiefly rock, (some fragments containing 1½ cu. ft.), with little or no clay, and was difficult to excavate.

At 61 ft., Elevation (231.5), there was a strong flow of water from the southwest. Here the material changed from seamy rock, very compact, with little clay, and became quite loose. The thickness of the loose material was about 1 ft. Smooth faces on a fragment of clay which was removed indicated the movement seam at Elevation (231).

Between June 20th and July 1st, 1898, more than 390 000 galls. of water were bailed from this shaft, and, later, the excavation was deepened to Elevation (223). The rock in the bottom appeared to be in place, but was full of seams.

Shaft No. 20.—This shaft was intended simply as an opening into an old drainage tunnel, built in 1894 to drain the ravine north of Reservoir No. 3. The work of opening the shaft and cleaning out the tunnel was begun on June 30th and completed on August 24th, 1898. The end of the old tunnel was reached at a point 234 ft. from the north end of Reservoir No. 3. Later in the season, work was resumed at this point, and an extension of the tunnel was begun which was carried, finally, to the western margin of the city property, a total distance of 304 ft. from the reservoir. This work was completed on February 23d, 1899.

Shaft No. 21.—The excavation for this shaft was made in the bottom of Reservoir No. 3, opposite the foot of the buttress wall on the west slope. The elevation of the surface of the concrete lining was (259.1). The depth of the excavation was 58 ft. Excavation was begun on December 23d, 1898, and completed on January 6th, 1899. Bed-rock was found at a depth of 58 ft., at Elevation (201). The surface of the rock was very hard and uneven, without seams.

For the entire depth, the material was blue, sandy clay, very hard and dry. No water was found.

Between depths of 39 and 41 ft., Elevation (218), several small sticks of wood were found, and among the sticks the fossil tooth

mentioned previously. At 50 ft., Elevation (209), there was found a small quantity of washed gravel.

Shaft No. 22.—This shaft is opposite the buttress, and about 100 ft. west of Reservoir No. 3. The surface elevation was (305.2), and the depth 57.2 ft. The excavation was begun on January 7th and completed on January 24th, 1899. For the first 26 ft. from the surface the material was chiefly yellowish sandy clay, full of seams. From 26 to 55 ft., Elevation (250), loose rock mixed with clay was found, followed by 1 ft. of fine broken rock, at Elevation (249), lying on top of the clay movement seam which was about 3 ins. thick. The elevation was (249) at the south and (248) at the north side of the shaft. Below the plane of the movement there was ½ in. of yellow clay. The total depth of the shaft was 57.2 ft. But little water was found.

Excavation West of the Power House.—Signs of undue pressure against the west wall of the power-house having appeared, it was decided to excavate a trench parallel with the building and extending out from the foundation for a few feet.

Work on this trench was completed on June 15th, 1898, the rock having been uncovered at Elevation (224.4). Just above the rock, blue clay was found, showing a line of cleavage, as though movement had taken place at that point, as had been suspected. The foundation of the power-house extended below the line of the slide and was immovable, although the earth adjacent to the wall was compacted very firmly.

Trench West of Dam No. 3 and North of Shaft No. 19.—On October 3d, 1898, the excavation of the trench near the west end of Dam No. 3 was completed. This trench was 14 ft. long, 3 ft. wide and 14 ft. deep, and was dug opposite a large crack in the parapet wall. The material was found to be broken rock mixed with clay, the quantity of clay diminishing toward the bottom. The mass appeared to have been broken and deranged by the pressure to which it had been subjected, but no secondary slip or line of movement was found.

A second trench, a few feet further north, and excavated a few days later, did not indicate any change in the material.

In addition to the foregoing, between February 21st and April 12th, 1898, eight 3-in. borings were made at various points on the sliding ground, ranging in depth from 42 to 121 ft., and aggregating a total depth of 655 ft., or 677 ft. including the work done in the bottom of Shaft No. 11. The contract price per foot for these holes was $0.60 in

earth and $1.25 in rock, the actual cost of the necessary casing, to be paid for at an extra price, and, in addition, wood and water for the engine was to be furnished to the contractor without charge. The total cost of the work amounted to $764.27, approximately, or $1.13 per linear foot.

TABLE No. 1.—Summary of Borings Made During 1895 and 1896.

No. of boring.	When begun.	When completed.	Surface elevation.	Depth of boring. in feet.
	1895.	1895.		
1	Sept. 27	Dec. 10	(223.7)	68.0
2	" 28	Oct. 15	(237.3)	72.0
3	" 30	Nov. 16	(264.3)	83.5
4	Oct. 30	" 6	(333.6)	106.8
5	Nov. 8	" 11	(369.0)	47.6
6	" 16	" 23	(409.3)	79.6
7	" 25	" 29	(460.3)	59.0
8	Dec. 2	Dec. 3	(461.2)	72.0
9	" 3	" 9	(458.4)	91.4
10	" 12	" 13	(458.9)	34.0
11	" 16	" 21	(426.0)	106.0
12	" 23	" 26	(397.5)	94.5
13	" 27	" 30	(344.3)	76.0
	1896.	1896.		
14 *C*	Jan. 20	Jan. 23	(311.3)	76.0
15	" 12	" 13	(340.4)	33.0
16	" 14	" 18	(347.9)	79.0
17	" 29	" 31	(313.8)	64.2
18 *B*	Feb. 4	Feb. 7	(311.7)	43.5
19	" 8	" 12	(303.5)	25.2
20	" 12	" 24	(296.9)	43.0
21 *B*	" 24	Mar. 5	(292.4)	77.5
22	Mar. 6	" 12	(298.4)	95.0
23	" 13	" 20	(305.9)	57.6
24	" 21	" 25	(308.8)	83.0
25	" 25	" 31	(308.9)	44.0
Total, from September 27th, 1895, to March 31st, 1896				1 710.4

TABLE No. 2.—Expenditure on Account of Borings Made During 1895 and 1896.

Date.	Contract account.	Material account.	Extra labor account. (Estimated.)	Total.
1895.				
Sept. and Oct.	....	$31.33	$150.00	$181.33
Nov.	$485.33	....	50.00	535.33
Dec.	592.40	5.00	50.00	647.40
1896.				
Jan.	349.87	104.87	50.00	504.74
Feb.	383.13	78.09	50.00	511.22
Mar.	366.25	78.55	49.50	494.30
Total	$2 176.98	$297.84	$399.50	$2 874.32

Cost of the Work: Linear feet of borings, 1 710; average cost per linear foot, $1.68.

TABLE No. 3.—SUMMARY OF BORINGS MADE DURING 1898.

No. of boring.	When begun.	When completed.	Surface elevation.	Depth of boring, in feet.
	1898.	1898.		
....	Feb. 1	Feb. 8	(449.4)	80.0
....	" 8	Mar. 9	(446.3)	75.5
....	" 22	Feb. 24	(430.2)	98.5
....	" 25	" 28	(425.5)	111.8
....	Mar. 12	Mar. 19	(408.0)	75.5
....	" 21	" 29	(368.2)	51.0
....	" 29	Apl. 8	(407.3)	121.0
....	Apl. 11	" 12	(346.4)	42.0
o. 11	Mar. 9	Mar. 11	....	22.0
tal, from February 1st, 1898, to March 11th, 1898				677.3

explorations required to determine the depth to bed-rock, e character of the overlying materials, described in the fore- pages, were completed early in 1899. While the excavation of afts was in progress, observations of the water levels in various and borings were taken at frequent intervals, in the hope of g some correspondence in such levels, but, with one or two ions, no indications were discovered showing any connection en the underground waters at the several shafts.

e results of the shaft and tunnel excavations, the measurement er levels and the rate of movement from month to month, were unicated to the consulting engineer as rapidly as the data were ed.

E No. 4.—EXPENDITURES ON ACCOUNT OF BORINGS MADE DURING 1898.

Date.	Contract account.	Extra labor account. (Estimated.)	Total.
1898.			
....	$227.50	$40.00	$267.50
....	365.00	40.00	405.00
....	71.77	20.00	91.77
otal	$664.27	$100.00	$764.27

st of the Work: Linear feet of borings, 667; average cost per linear $1.13.

TABLE No. 5.—SUMMARY OF SHAFT AND TUNNEL WORK, COMPLETED DURING THE YEARS 1897, 1898 AND 1899.

No. of shaft.	When begun.	When completed.	Surface elevation.	Bed-rock elevation.	Depth of slide, in feet.	Depth of shaft, in feet.	Length of tunnel, in feet.
1	July 19, 1897	Jan. 1, 1898	(435.0)	(360.0)	75.0	75.0	....
2	" 19, 1897	Aug. 20, 1897	(408.0)	(297.0)	111.0	112.0	....
3	Aug. 9, 1897	" 10, 1897	(467.5)	....	....	10.0	....
4	" 11, 1897	" 23, 1897	(530.5)	(457.5)	73.0	73.0	32
5	" 23, 1897	Sept. 21, 1897	(379.6)	(278.2)	101.4	101.4	....
6	Sept. 17, 1897	" 29, 1897	(368.5)	(322.5)	48.0	50.0	....
7	" 21, 1897	Dec. 23, 1898	(311.0)	....	*15.0	53.5	1-74 1-70
8	Oct. 4, 1897	Oct. 16, 1897	(446.4)	(383.4)	62.7	63.0	38
9	" 19, 1897	Nov. 3, 1897	(460.8)	(408.0)	52.8	55.5	....
10	Nov. 2, 1897	" 5, 1897	(445.8)	....	....	23.5	....
11	" 5, 1897	Dec. 8, 1897	(462.9)	(395.0)	67.9	51 + boring 23 ft.	....
12	" 5, 1897	Nov. 27, 1897	(442.2)	....	....	25.5	39
13	Dec. 18, 1897	Jan. 6, 1898	(531.9)	(454.0)	75.9	81.5	....
14	Jan. 31, 1898	Feb. 26, 1898	(506.1)	(437.1)	69.0	69.0	....
15	Feb. 28, 1898	April 9, 1898	(347.4)	(232.6)	109.0	115.0	....
16	April 9, 1898	May 17, 1898	(331.7)	(234.7)	96.5	98.0	....
17	" 20, 1898	" 20, 1898	(407.6)	(304.6)	102.0	108.0	....
18	May 18, 1898	Dec. 16, 1898	(318.1)	(223.0)	86.5	115.5	131
19	June 8, 1898	July 30, 1898	(292.5)	(231.0)	60.5	69.5	....
20	" 30, 1898	Feb. 23, 1899	(314.8)	....	....	18.0	70
21	Dec. 23, 1898	Jan. 6, 1899	(259.1)	(201.1)	....	58.0	....
22	Jan. 7, 1899	" 24, 1899	(305.2)	(248.0)	56.2	57.2	....
Trench W. of power-house	....	June 15, 1898	....	(224.0)	....	6.0	....
Trench W. of Dam No. 3	....	Oct. 3, 1898	....	....	....	14.0	....
Totals					1 260.4	1 497.1	454

Average depth of slide, $\frac{1\,245.4}{16} = 77.8$ ft.

* Not included in average of depth of slide.

Summarizing, in a general way, the results of the surveys and examinations, then completed, it may be said that, after a careful study of all the facts collated, the following conclusions were reached:

(1) The approximate length of the sliding ground was 1 700 ft.

(2) The approximate width of the sliding ground along the west margin of reservoirs was 1 100 ft.

(3) The approximate width of the sliding ground at its west end was 400 ft.

(4) The approximate surface area of the sliding ground was 29.27 acres.

(5) The approximate bed-rock area of the sliding ground was 23.65 acres.

(6) The approximate area of the water-shed, which includes the western end of the sliding tract, was 26.46 acres.

(7) The minimum depth of the body of the slide (Shaft No. 6) was 46 ft.

(8) The maximum depth of the body of the slide (Shaft No. 2) was 112 ft.

(9) The average depth of the slide at sixteen shafts in the main body of the slide was 77.8 ft.

(10) The approximate volume of the sliding mass was 3 400 000 cu. yds.

(11) The approximate weight of the sliding mass was 4 600 000 tons.

TABLE No. 6.—EXPENDITURE ON ACCOUNT OF SHAFTS AND TUNNELS, DURING 1897, 1898 AND 1899.

Date.	Labor.	Pumping.	Materials.	Total cost.
July, 1897	$131.00	....	$64.60	$195.60
Aug. "	490.80	....	177.22	668.02
Sept. "	624.25	....	71.38	695.63
Oct. "	206.65	$181.00	93.94	481.59
Nov. "	441.80	192.00	52.60	686.40
Dec. "	306.95	174.25	66.24	547.44
Jan. 1898	112.00	152.90	12.86	277.76
Feb. "	190.25	43.40	28.43	262.08
Mar. "	195.75	....	27.09	222.84
Apr. "	256.05	....	43.70	299.75
May "	319.00	....	27.58	346.58
June "	348.10	16.75	64.68	429.53
July "	321.10	62.50	61.55	445.15
Aug. "	178.25	48.75	27.41	254.41
Sept. "	177.30	....	39.87	217.17
Oct. "	399.15	47.50	183.90	630.55
Nov. "	423.50	65.00	63.95	552.45
Dec. "	358.00	....	....	358.00
Jan. 1899	192.05	....	62.05	254.10
Feb. "	316.60	....	6.00	322.60
Mar. "	77.15	....	....	77.15
Total	$6 065.70	$984.05	$1 175.05	$8 224.80

Estimate of work done:

Shaft excavation..........................1 497 lin. ft.

Tunnel excavation: 454 lin ft., equivalent to shaft excavation, 454 × 2, or .... 908 " "

Total estimated shaft excavation........2 405 " "

Cost per linear foot $3.42

Laborers' wages were $1.75 per day of 10 hours.

(12) With each returning dry season there was a marked lessening of the movement, followed by an increase during the winter, indicating an intimate relation between the volume of monthly rainfall and the rate of movement, as shown by Table No. 7, prepared in January, 1899, and covering the surveys completed to that date.

TABLE No. 7.

Time of Observation.	Total rainfall, in inches.	TOTAL MOVEMENT, IN FEET.		Average maximum movement per month, in feet.
		Minimum.	Maximum.	
Dec., 1895, to May, 1896, inclusive..	27.58	1.09	1.30	0.22
June, 1896, to Nov., 1896, " ..	18.08	0.25	0.45	0.08
Dec., 1896, to May, 1897, " ..	21.74	0.71	0.84	0.15
June, 1897, to Nov., 1897, " ..	18.69	0.03	0.14	0.03
Dec., 1897, to May, 1898, " ..	25.88	0.05	0.15	0.03
June, 1898, to Nov., 1898, " ..	13.12	0.00	0.08	0.01

The readings are the minimum and maximum average movement at eight different points along the center of the slide, between Reservoir No. 4 and the "round top."

The figures denoting the rainfall have been compiled from the reports of the United States Weather Bureau. The observations were taken at the Weather Bureau office, in the City of Portland, 1½ miles distant from the sliding land tract. Elevation about (150). It may also be stated that the six-month period following the last one given in the table showed a very marked increase in the rate of the movement.

(13) The surveys thus far made do not determine that the movement is at a uniform rate at the center and along the sides of the sliding ground, but probably there is little difference.

(14) Apparently, the movement at the surface and on the bed-rock are uniform.

(15) Apparently, there is a slight southerly movement taking place near the west end of the slide and a northerly movement as well at the central portion, the bed-rock being slightly inclined in these directions as well as to the eastward.

The inclination of the bed-rock at different points on the slide is shown by Table No. 8.

(16) The uniformity of the movement of the slide is indicated by the absence of surface cracks across the central portions of the sliding tract.

TABLE No. 8.—Bed-Rock Elevations and Slopes.

No. of shaft.	Elevation of bed-rock.	No. of shaft.	Elevation of bed-rock.	Distance between shafts, in feet.	Difference in elevation, in feet.	Slope of bed-rock.	Direction of slope of bed-rock.
4............	(458)	13	(454)	214	4	1 on 53.5	S.
3............	(454)	14	(437)	234	17	1 " 13.8	E.
4............	(437)	9	(408)	198	29	1 " 6.9	E.
9............	(408)	11	(395)	250	13	1 " 19.2	N.
1............	(395)	8	(383)	298	12	1 " 24.8	N.
4............	(458)	8	(383)	518	75	1 " 6.9	N. E.
1............	(395)	1	(360)	268	35	1 " 7.6	E.
1............	(360)	2	(297)	248	63	1 " 3.9	E.
3............	(383)	17	(305)	420	78	1 " 5.4	E.
7............	(305)	16	(235)	362	70	1 " 5.2	E.
7............	(305)	7	(Tunnel) (249)	466	56	1 " 8.3	N. E.
7............	(Tunnel) (249)	19	(231)	392	18	1 " 21.8	S. E.
9............	(231)	Power-house.	(224)	194	7	1 " 27.7	S. E.
2............	(297)	15	(233) (Mo'm't)	252	64	1 " 3.9	E.
2............	(297)	18	(231)	388	66	1 " 5.9	E.
3............	(323)	18	(231)	424	92	1 " 4.6	N. E.
5............	(233)	18	(231)	170	2	1 " 85.0	S. E.
9............	(231)	18	(231)	432	0	1 " 0.0	S.
2............	(297)	5	(278)	334	17	1 " 19.6	N.
3............	(235)	19	(231)	196	4	1 " 49.0	S. E.
9............	(408)	6	(323)	510	85	1 " 6.0	E.
7............	(305)	5	(278)	166	27	1 " 6.1	E.
5............	(278)	16	(235)	228	43	1 " 5.3	N. E.

(17) That the movement originated in the unstable mass near the restern end of the sliding ground is indicated by the condition of he joints in the rails of the cable road where running east and west. When first examined, in September, 1895, these joints were all tightly losed. The rails were also distorted at the angle just east of Shaft No. 6, as shown in Fig. 2, Plate VI. These conditions seem to point o the conclusion that the pressure was mainly from above and that here had been no drawing away of the foot of the slope at the reservoirs; or, in other words, that the movement did not originate at the eservoirs.

(18) The breaks in the lining of Reservoirs Nos. 3 and 4, and also t the buttress built against the lining of Reservoir No. 3, have been aused by the movement of the slide, and are not due to local slips, s at first supposed.

(19) From the shaft excavations, the character of the materials forming the mass of the slide has been determined to be largely of broken rock of small size mixed with clay. Across the central portion of the slide, in the vicinity of Shaft No. 1, the clay and fine

material predominate, forming a dike measurably impervious to water. Eastward from that point, the material contains less clay and does not hold a large quantity of water.

To the west of Shaft No. 2, and also near the head of the slide, the excavations developed at some points quite a body of clay. Between Shafts Nos. 1 and 11, and still further west, water pockets of considerable magnitude have been found. From the pocket in connection with Shaft No. 1 more than 3 900 000 galls. of water were pumped before the supply was exhausted; and, from the one connected with Shaft No. 11, about 500 000 galls. were pumped before work was abandoned at that point, this effort having lowered the water but a few feet.

(20) As a rule, there seemed to be no direct connection between the different bodies of underground water, or between the several shafts and borings.

(21) The several bodies of water discovered were all in close contact with the clay stratum forming the bed of the slide, and, undoubtedly, have had much to do with the continuance of the movement. This is shown by the decrease in the movement which occurred between December, 1897, and November, 1898, during which period the underground reservoir connected with Shaft No. 1 was drained by pumping. Fig. 4 is a profile showing the elevation of the water standing in the shafts.

(22) Comparing the rate of movement of the slide at different seasons of the year with the volume of the rainfall during the same period, and noting also that a greatly reduced motion ensued during the time that the drainage of Shaft No. 1 was in progress, succeeded by an increased movement during the following winter when the shaft was again filled, it seems reasonable to conclude that the movement was largely if not entirely due to the presence of water in the underground reservoirs. It follows naturally, therefore, that the permanent removal of underground waters would produce a permanent cessation of the movement.

The conclusions of the consulting engineer were practically in accord with the foregoing statements. His report also contained interesting references to the probable origin of the slide, as well as recommendations regarding the best method of overcoming the difficulty.

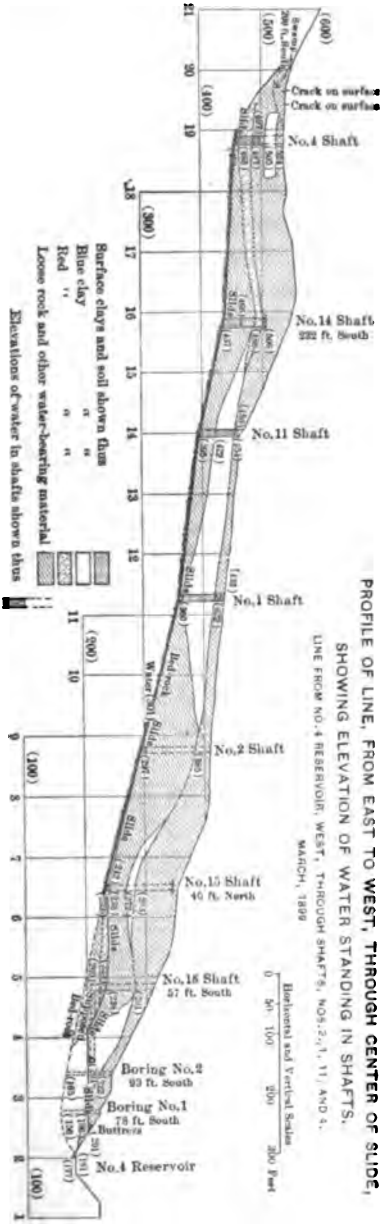

PROFILE OF LINE, FROM EAST TO WEST, THROUGH CENTER OF SLIDE,
SHOWING ELEVATION OF WATER STANDING IN SHAFTS.
LINE FROM NO. 4 RESERVOIR, WEST, THROUGH SHAFTS, NOS. 2, 1, 11, AND 4.
MARCH, 1899
Horizontal and Vertical Scales
0 50 100 200 300 Feet
Crack on surface
Crack on surface
No. 4 Shaft
No. 14 Shaft
232 ft. South
No. 11 Shaft
No. 1 Shaft
No. 2 Shaft
No. 15 Shaft
40 ft. North
No. 16 Shaft
57 ft. South
Boring No. 2
93 ft. South
Boring No. 1
78 ft. South
Buttress
No. 4 Reservoir
Bed rock
Water
Slide
Surface clays and soil shown thus
Blue clay " "
Red " " "
Loose rock and other water-bearing material
Elevations of water in shafts shown thus

FIG. 4.

Before proceeding to discuss the remedy proposed by the consulting engineer, and the action taken subsequently in connection therewith, mention should be made of a matter which at one time overshadowed all other interests completely, threatening as it did an enormous property loss to the city.

During the latter part of the year 1897, after it became known that the Water Committee had entered upon an examination of the sliding-land question with the view of determining the best method of restoration, the owners of about five-sixths of the moving ground instituted a suit against the city for damages to their property. They claimed that the excavation of the reservoirs, in the autumn of 1893 and in the spring and summer of 1894, was the cause of the movement, and in consequence of this movement their property had been damaged to an amount aggregating $439 000.

Two of these suits were filed within a few months of each other. The first was filed on February 16th, 1898, by the King Real Estate Association, claiming damages to land, $169 000, and for injury to the cable railway in which they were interested, $100 000, making a total of $269 000. The second suit was begun on May 2d, 1898, by L. F. Grover *et al.* who claimed damages to 22.5 acres of land, at $5 000 per acre, or $110 000, and for damages to the cable railway in which they were interested, $60 000, making a total of $170 000.

The value of these tracts of land, as given on the assessment roll for the year 1897, was as follows:

King Real Estate Association, 97 acres.........	$33 000
Grover *et al.* West End Addition, 51 acres......	28 100
Grover *et al.* West End Addition, 77 "	23 000
Total assessed valuation...............	$84 100

The claim made by the plaintiffs in these suits, that the excavation of the reservoirs was the primary cause of the movement of the adjacent hillside, was not regarded by the Water Committee as tenable, and it was contested strongly. The suits were fought by the city attorney at every stage. In consequence of these dilatory proceedings, the issues were not fully made up and the trial begun until November 7th, 1899.

The report of the consulting engineer had been submitted to the Water Committee during the preceding March, but had been with-

held from publication, on account of the damage suits which had been instituted, and in order not to appear to prejudge the case in advance of the trial. It was also desired that the conclusions of the report should be presented first in the form of testimony for the defense upon the trial then in prospect.

During the year 1899, the time of the engineers was largely engrossed in the study of the sliding-land data already gathered, and in preparing maps, plans, profiles and exhibits of various kinds for use in the coming trial, or to illustrate some new phase of the problem in hand.

The trial, which was begun on November 7th, 1899, was of exceeding interest, and importance, as well, both on account of the novelty of the conditions leading to its inception and the magnitude of the pecuniary interests involved. The case was studied closely by the city attorney, who was early impressed by the fact that the cable road had been in successful operation for nearly a year prior to the beginning of reservoir construction, and, as far as then known, there had been no difficulty in its operation. This was regarded as a strong point for the plaintiff, and as indicating, that the reservoir excavation was the originating cause of the movement.

The investigations made by the engineers seemed to point conclusively to the fact that the movement of the slide must have been in progress for some years, at least intermittently, but it was impossible to determine when the movement began. Owing to the fact that the hillside was covered originally with a dense forest of firs and cedars, with a smaller growth of vine, maple and alder, of which it had been cleared but a short time prior to the construction of the cable road, it would have been exceedingly difficult if not impossible to determine the existence of any movement from a simple inspection of the ground, especially when the monthly or yearly change was as slight as it is known to have been in this instance. In further explanation of the difficulties attending such observations, it may be said that when reservoir construction was begun, the banks of the ravine in which the reservoirs are located were covered with fallen timber and dense brush, and the upper or western third of the sliding tract is, to this day, covered with brush, which, during the summer months, effectually shields the ground from observation, making imperative the use of instruments in order to gain even an approximate measurement of any movement which may be taking place.

When the facts supporting the theory of "an ancient slide" were placed in the hands of the city attorney, he at once began a campaign of investigation and search to determine the location of the men employed in surveying, building and operating the cable road during the two years that elapsed between the time that the work was begun and the final abandonment of the enterprise. The search continued for months, and, when the day of trial came, the mass of testimony which had been accumulated (all tending to substantiate the claim that the movement of the hillside was in progress when the cable road was completed, a year prior to the commencement of reservoir construction), must have been a surprise to the plaintiffs. So many witnesses were offered to testify to a movement of the cable track at certain points that the Court declined to hear them all, considering that fact established beyond question. The witnesses who testified on these points included the contractor who built the line, and the inspector and car men who operated the road after it was built, all of whom testified to the difficulties experienced in maintaining bridge bents in a vertical position on the east and west line, and the alignment of the cable conduit and rails where they crossed the slide from north to south. The contractor also recounted some of his experiences in forcing the track back into line, so as to admit of cars passing in safety, and to insure its acceptance by the company.

The engineers engaged as expert witnesses for the city formulated the theory of an "ancient slide" and showed the depth and character of the material forming the mass of the slide, as well as the inclination of the bed-rock and the presence of a stratum of plastic clay, with an abundance of water stored in the interstices of the rock in immediate connection therewith, all supported by the data to which reference has been made herein. They were also fortified by a number of plans and "exhibits" prepared especially for use on the trial, to which it may be interesting to refer briefly.

The principal one of these exhibits, and in many respects the most valuable of all, was a plaster-of-paris model of the reservoirs and the sliding ground, including also the water-shed surrounding the head of the "slide," made on a scale of 1:600, which was prepared by the Water Committee's engineers. This model showed the original ravines in which the reservoirs are located and the volume of the material removed in excavating the reservoir basins, as well as the location and

depth of the ravines which were filled by the property owners, without adequate under drainage. The mass of the slide was also cast in a separate block which could easily be removed so as to show the depth of the slide and the inclination of the bed-rock on which the movement was then taking place. From this model was shown the relative insignificance of the volume of the material removed in excavating the reservoir basins, which amounted to only about 3% of the mass of the slide, and the improbability that the removal of this small volume could have caused a movement of the slide of the magnitude known to exist.

Another interesting exhibit used upon the trial was a diagram showing a comparison of the volume of the rainfall and the movement of the slide for corresponding months, from January, 1895, to the date of the trial. This diagram has since been extended so as to cover the entire period during which the surveys have been continued. This diagram is shown in Plate XII.

The measurement of rainfall was taken from the reports of the United States Weather Bureau in Portland. It is to be noted that while the amount of precipitation is extremely large for some months, notably 13.12 ins. for November, 1896, the average for any one season rarely exceeds 44 ins.

The movement, as recorded on the diagram, is the average of fourteen points observed at intervals along the central portion of the sliding ground, where the maximum movement was supposed to have taken place, from September, 1895, to December, 1899. Since the latter date the average of a large number of points has been taken, two hundred and sixty points having been established and observed regularly. The average of the readings at fifty-one of these points, along a central belt 100 ft. wide, has been used in plotting the diagram of movement for 1900–1903. Merely casual inspection and comparison will serve to show the apparently close relation which exists between the volume of the rainfall during what may be called the wet and dry seasons of the year—say, from December to May, inclusive, for the former, and from June to November, inclusive, for the latter—and the movement of the slide during the same period. It will be seen from the diagram that with each recurring dry season there was a corresponding cessation of the movement, and that with the beginning of the winter rains the movement increased. It is to be

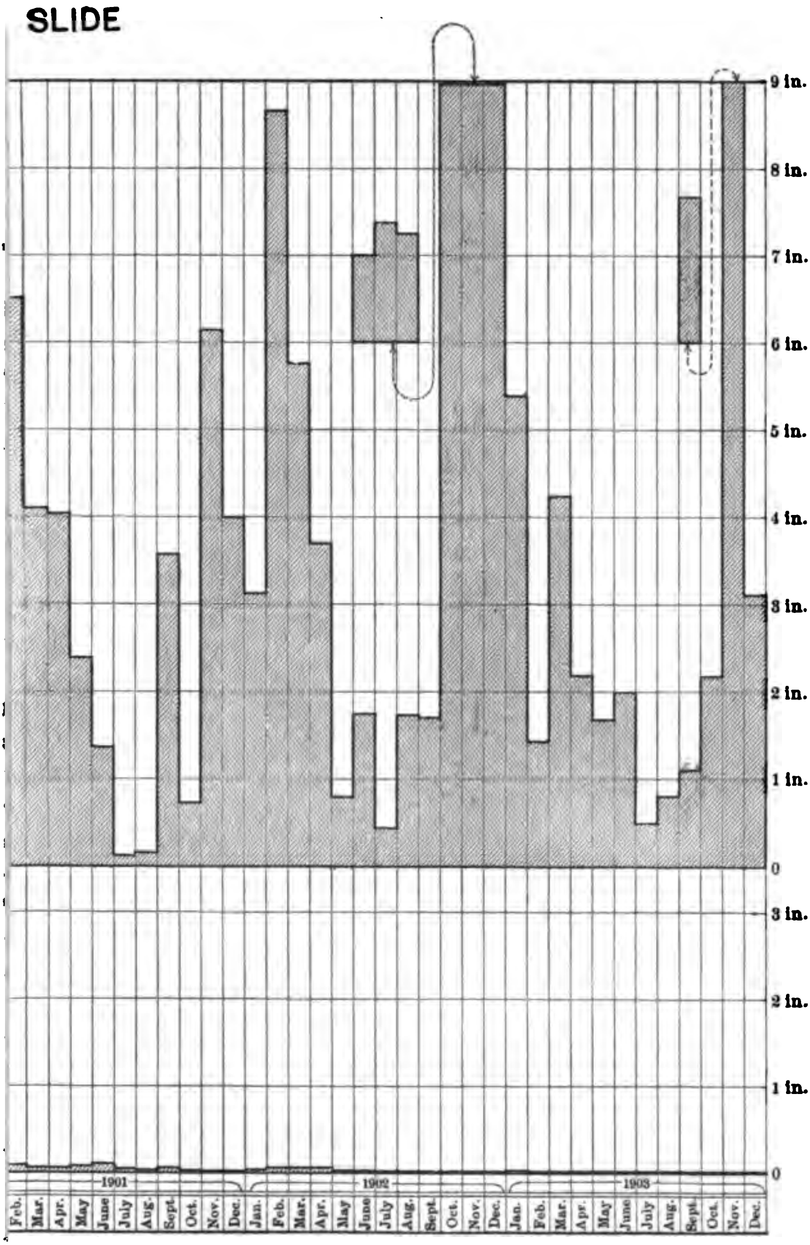
noted, also, that, in each instance, an interval of about one month elapsed between a change in the volume of rainfall and the corresponding change in the rate of movement.

An inspection of the diagram will show at once one irregularity in the yearly movement, namely, a marked increase in the monthly movement during the winter months is followed usually by a corresponding diminution with the return of dry weather. The explanation of this irregularity in the movement, which occurred during the years 1897 and 1898, forms one of the most interesting of the developments which have occurred since the study of this problem was begun.

It will be recalled that while the excavation of Shaft No. 1 was in progress considerable water was found, the draining of which was accomplished by deep-well pumps. The draining of this well was in progress from August 19th, 1897, until January 31st, 1898, the total volume of water removed during that period being more than 3 900 000 galls. Even then, the underground reservoir had not been drained thoroughly, for, when pumping ceased, the water rose in the shaft to a height of several feet.

By observing the diagram it will be noted that when pumping from this shaft was in progress, the movement did not increase as rapidly during the winter months as it had during former seasons, although there was a slight increase from August to February when the maximum for that year was reached. The movement for February, 1898, was only 0.30 in., as compared with 2.69 ins. for February, 1897, and 0.85 in. for February, 1899. Perhaps this irregularity can be shown best by comparing the total movement for the entire season preceding with the total movement for the season following the drainage operations. From May, 1896, to May, 1897, the total movement was 13.10 ins. From May, 1897, to May, 1898, during a portion of which period pumping was in progress, the total movement amounted to only 1.57 ins.; and this was followed by an increase to 3.69 ins. during the year beginning May, 1898, and ending May, 1899.

It is probable that the decreased movement noted during the year 1898 was due in part to the pumping of water from Shaft No. 18, in July and August, amounting to 650 000 galls., and from Shaft No. 11, in October and November, amounting to 540 000 galls., but it is believed to have been due principally to the thorough drainage of the


SLIDE
9 in.
8 in.
7 in.
6 in.
5 in.
4 in.
3 in.
2 in.
1 in.
0
3 in.
2 in.
1 in.
0
1901
1902
1903
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

lerground reservoir connected with Shaft No. 1. As has been ted, the drainage of this body of water was practically completed January, 1898, pumping having been suspended on the 31st of that nth, and the water was thereafter allowed to accumulate, the rise the shaft indicating the rate at which the reservoir was being filled. is rate was noted carefully, and it was observed that the under-und reservoir was not filled to its original height until the end of cember of that year.

During the period when this underground reservoir was being ined, and for some months thereafter, the movement was at a atly diminished rate. When the underground reservoir was again ed the rate of movement began to increase until it was more than uble that of the preceding year, and this uniformity of rise and fall s continued for the two seasons following.

It was this seeming coincidence of the cessation of the movement th the draining of the underground reservoir at Shaft No. 1 which st changed conviction into certainty that the cause of the slide was be found in the underground water stored in various portions of the ding ground, and hence it followed that a remedy for the difficulty s to inaugurate a thorough system of drainage.

This diagram was one of the most important and convincing "ex-bits" introduced by the Water Committee in defending the suit, as showed, clearly, that the movement depended more, and chiefly, on the volume of water falling upon the surface and stored in derground reservoirs in the interstices of the broken rock forming large portion of the mass of the slide, than upon the removal of a all fragment of earth from the toe of the slope. In addition to the regoing, a number of cross-sections of the sliding ground, and tables owing the results of surveys, etc., were introduced at the trial. The oss-sections are shown on Plate IX.

The trial of the damage suit of the King Real Estate Association, e first one instituted, was begun on November 9th, and was rminated on November 28th, 1899, in a verdict in favor of the city.

The expert witnesses who testified for the plaintiff were Arthur L. dams, M. Am. Soc. C. E.; Franklin Riffle, M. Am. Soc. C. E., and W. . Crondahl, C. E. Those who testified for the city were Col. G. H. lendell, M. Am. Soc. C. E., Consulting Engineer (since deceased); eorge L. Dillman, M. Am. Soc. C. E.; F. I. Fuller, M. Am. Soc. C. E.,

and J. A. Hurlbut, C. E. The testimony of these witnesses was of an exceedingly interesting character, but special reference to it at this time is omitted purposely, in the hope that some of these gentlemen will participate in the discussion of this paper, giving the results of their investigations and conclusions.

As a result of this verdict the second suit was not pressed for trial, although an attempt was made by the city to have it set for an early date. In a few weeks, however, the several owners of the sliding land made overtures to the Water Committee to sell to the city a large tract, nearly 60 acres, including the sliding land and surrounding water-shed, for a sum which was regarded as reasonable, and the purchase of this land was completed a few months later. Thus the Water Committee acquired control of all the lands adjacent to the reservoirs, and sloping thereto, and hence will be able to eliminate all danger of complications which might arise through occupation of the premises by private owners. This tract, ultimately, will be added to the present City Park, which it adjoins, making an area of more than 100 acres available for park purposes.

The purchase of the sliding-land tract by the city was concluded in May, 1900, the terms arranged with the property owners including an agreement for the construction of a 24-in. sewer to convey the surface drainage from the upper portion of the King ravine water-shed into the Washington Street sewer, north of the reservoirs, this sewer to be completed prior to October 1st, 1901. The drainage from this ravine, originally, was provided for by a 24-in. sewer which passed near the north end of Reservoir No. 3, and thence through the Park to the main sewer in Washington Street. The new sewer was proposed as an additional safeguard.

During June, 1900, the writer presented to the Water Committee a statement of the work then accomplished and the reasons for believing that the slide could be stopped by a thorough system of under-drainage along bed-rock, as recommended by the consulting engineer and supported by the testimony of the engineers engaged as expert witnesses upon the trial of the King damage suit, in behalf of the plaintiff as well as the defendant, and requested authority to undertake the immediate construction of the drainage tunnels in question. This report was accompanied by a map showing the main drainage tunnels proposed. The plan proposed by the consulting engineer called for

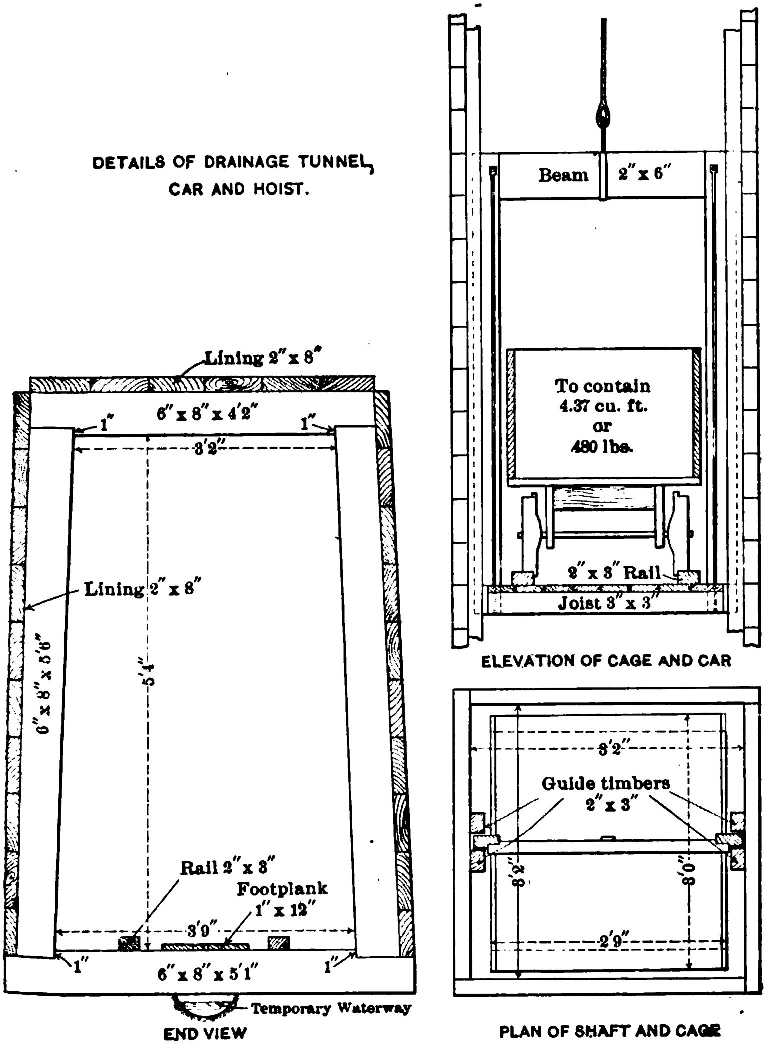

DETAILS OF DRAINAGE TUNNEL, CAR AND HOIST.
Lining 2" x 8"
6" x 8" x 4'2"
1"
1"
3'2"
Lining 2" x 8"
6" x 8" x 5'6"
5'4"
Rail 2" x 3"
Footplank 1" x 12"
3'9"
1"
1"
6" x 8" x 5'1"
Temporary Waterway
END VIEW
Beam 2" x 6"
To contain 4.37 cu. ft. or 480 lbs.
2" x 3" Rail
Joist 3" x 3"
ELEVATION OF CAGE AND CAR
3'2"
Guide timbers 2" x 3"
8'2"
8'0"
2'9"
PLAN OF SHAFT AND CAGE

Fig. 5.

the construction of the main tunnel leading west from Reservoir No. 4 to the line of the old cable track on Kingston Avenue, and left the question of branches, or the further extension of the main tunnel, to be determined as the work progressed. Upon this presentation, the writer was directed by the Water Committee to begin the work of tunnel construction at once. All preliminary arrangements were soon made, and the work of excavation for the drainage tunnels was begun on July 2d, 1900.

The size of the tunnel was fixed at the smallest dimensions that would conveniently answer, the inside dimensions being 3 ft. 2 ins. wide on top, 3 ft. 9 ins. wide at the bottom, with a clear height of 5 ft. 4 ins. The timbers used were 6 x 8-in. spaced at 3-ft. centers, with 2 x 8-in. lagging. The required excavation approximated 1.25 cu. yds. per linear foot of tunnel. (See Fig. 5.)

The plan adopted for the prosecution of the work called for the commencement of the excavation at the lower end of the tunnel at the bottom of Reservoir No. 4, and also at one or more of the exploration shafts which had been opened to bed-rock two years before, the line adopted for the main tunnel passing through Shafts Nos. 18, 2 and 1 to Shaft No. 11 at the cable road. These shafts were made 3 ft. 2 ins. square, in the clear. To expedite the work at these shafts, a small hoist was constructed to be operated by a steam engine, similar to those in use by builders. This hoist, necessarily, was of rather diminutive size, the platform being only 25 ins. wide in the clear between the side timbers, and about 30 ins. long. Several small dump cars, of such size as could be carried safely upon the platform of the hoist, were made, the capacity of the box being about 5 cu. ft. The gauge of the track was 18 ins. The wheels were 9 ins. in diameter. These cars were run on a strap-iron track laid on 2 x 4-in. stringers on the floor of the tunnel, and, when filled, were pushed by hand to the foot of the shaft and thence hoisted to the surface and dumped. In most cases the grade of the tunnel was sufficient to take the car from the heading to the shaft by gravity, the empty cars being pushed back by hand. This arrangement proved to be quite effective and economical.

To expedite the work, day and night crews were employed, for a time, at two different headings, until the tunnel had been completed as far as Shaft No. 2. From that point only one heading was worked, although day and night crews were employed, each working a ten-hour shift.

Comparatively little water was encountered during the early stages of the work, and it was not until October 30th, when the tunnel reached the vicinity of Shaft No. 1, a distance of 890 ft. from Reservoir No. 4, that water was found in any considerable quantity. At this point, the water stored in Shaft No. 1, then standing at a depth of 70 ft., was drained away. A few days later the tunnel was carried to the foot of the shaft, 912 ft. from Reservoir No. 4, and connection was made with the water-bearing stratum from which the shaft had been supplied. For a number of hours the discharge of water from this source was so strong that it overflowed the box gutters prepared for it, and caused the suspension of all work. The flow diminished somewhat within an hour or two, but it was estimated that approximately 1 800 000 galls. were drained away within the next twenty days, by which time the flow had diminished to about 25 000 galls. per day.

About the middle of January, 1901, the tunnel excavation had reached Shaft No. 11, 1 175 ft. from Reservoir No. 4. The water standing in this shaft was drained away safely, but the flow from the loose material surrounding the shaft continued at the rate of 165 000 galls. per day for a number of days. Before reaching this shaft, the tunnel passed through a wall of light-colored clay, some 18 to 20 ft. in thickness, and so dense and compact that very slow progress could be made with the excavation. Only a small fragment could be removed on the point of a pick, and at times wedges were used to break out blocks of the material.

The finding of this wall of compact material to the eastward of this shaft was confirmatory of the diagnosis of the consulting engineer, for, apparently, this wall or dike of clay was holding back the water in the underground reservoir in exactly the same manner as was done by the body of clay found to the eastward of Shaft No. 1. In both instances the body of clay was so compact as to be practically impermeable to water.

The flow of water from the underground reservoir at Shaft No. 11 proved to be so strong that it interfered with the continuance of the tunnel work at that point, and, accordingly, the tunnel party was moved back to Shaft No. 1, from which point a branch tunnel was started in a northwest direction toward Shaft No. 8. This tunnel was begun in January, 1901, and on March 29th was completed to Shaft

No. 8, a distance of 427 ft. Only small quantities of water were found in this tunnel. A small quantity had accumulated in Shaft No. 8 and the short tunnel connected therewith.

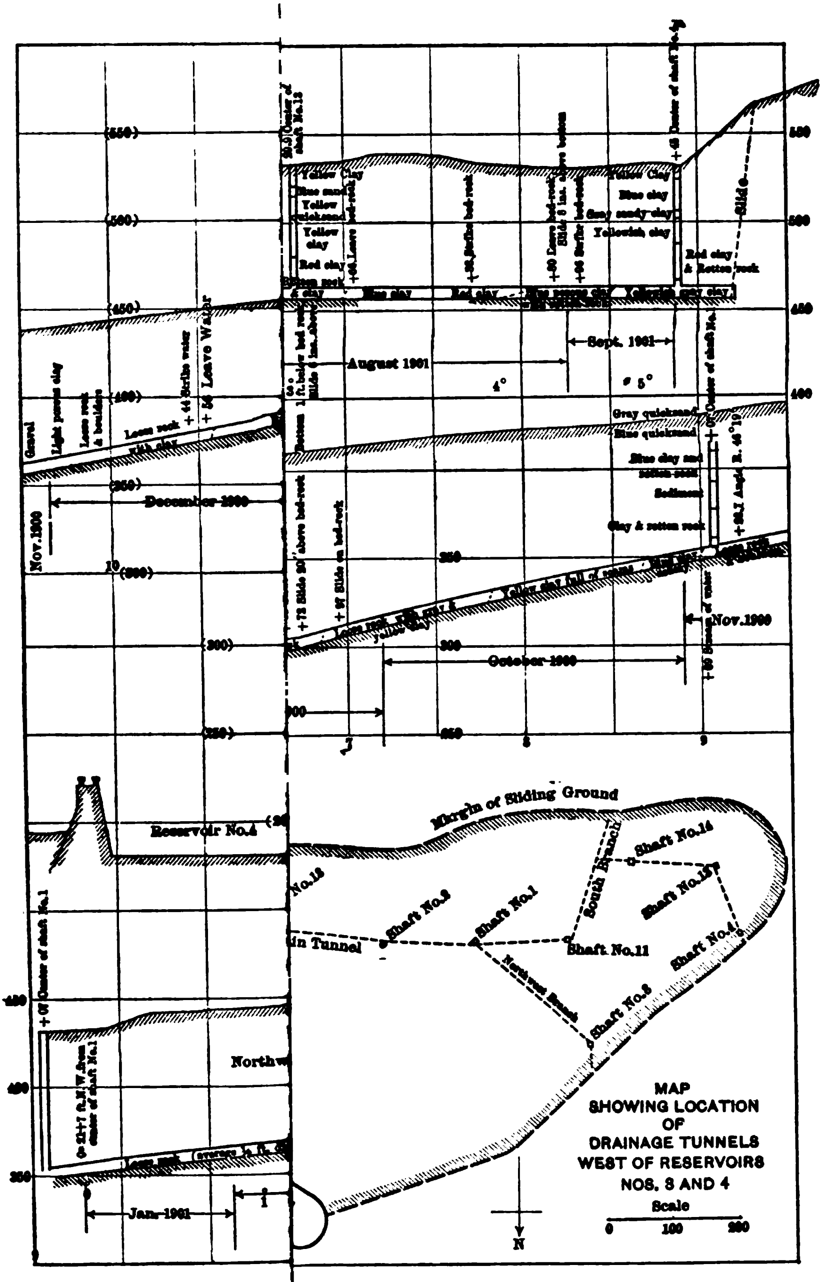
Work on the main tunnel, at Shaft No. 11, was resumed in April, the water stored in the interstices of the rock having drained away by that time, so as to admit of the continuation of the tunnel excavation with some degree of comfort. The flow, however, continued for some time at the rate of from 50 000 to 60 000 galls. per day.

Instead of running west from this point, on the course laid down originally, it was decided to deflect the tunnel to the southwest so as to reach the southern limit of the slide, thus, with the northern branch, covering the entire width of the sliding ground and serving to cut off any and all bed-rock drainage from the west.

The southern rim of the slide was reached on June 14th, 1901, the tunnel excavation having passed beyond the limit of the water-bearing material and into dry clay. The line of the movement at the margin of the slide was defined plainly between two masses of yellow clay, the marginal slope being 1.2 vertical to 1 horizontal, from the tunnel level to the surface of the ground.

TABLE No. 9.—Cost of Drainage Tunnels, June, 1900, to December, 1901.—Expenditures for Materials and Labor, Exclusive of Surveys and Superintendence.

Date.	Linear feet constructed.	Average cost per linear foot.	Total cost.
1900.			
June	....	....	$87.71
July	157	$5.14	807.16
August	308	4.28	1 317.88
September	257	5.18	1 330.48
October	169	5.18	876.01
November	76	14.11	1 072.61
December	161	5.31	854.62
1901.			
January	131	7.54	987.77
February	167	4.66	777.80
March	180	5.18	933.29
April	96	9.35	898.96
May	175	5.46	956.17
June	170	5.72	972.18
July	182	4.78	870.78
August	217	5.01	1 086.80
September	61	5.30	323.00
October	....	....	9.32
November	....	....	....
December	....	....	....
Totals	2 507	$5.65	$14 161.14


August 1901
Sept. 1901
December 1900
Nov. 1900
October 1900
Jan. 1901
Leave Water
Yellow Clay
Blue clay
Red clay
Red clay & Rotten rock
Gray quicksand
Blue quicksand
Sediment
Clay & rotten rock
Margin of Sliding Ground
Reservoir No. 4
Shaft No. 14
Shaft No. 13
Shaft No. 1
Shaft No. 11
Shaft No. 5
Shaft No. 4
South Branch
Northwest Branch
MAP
SHOWING LOCATION
OF
DRAINAGE TUNNELS
WEST OF RESERVOIRS
NOS. 3 AND 4
Scale
0
100
200
N

When the excavation had reached this point, the Committee decided to continue the tunnel to the extreme western end of the slide in order to insure the drainage of all large water deposits. This western extension of the tunnel was begun in June, 1901, and, passing through Shafts Nos. 14 and 13, was completed on September 11th, to Shaft No. 4 near the extreme western end of the sliding tract. The force was then disbanded. The total length of drainage tunnel completed during the fourteen months that the work was in progress was 2 507 lin. ft., costing, for material and labor, $14 161.

The wages paid were: Outside laborers, $2 per day of 10 hours; tunnel men, $2.25 and $3 per day.

The main characteristics of the material encountered in the tunnel are shown upon the profile of the tunnel line, Plate XIII, but the following details may be of interest:

When the drainage tunnel was commenced, the initial point was established at the lowest point in the reservoir bottom, opposite the gate-house, from which point a 12-in. drain pipe, laid during the original construction, connected with the main sewer. Borings, made in 1895–96, had developed the fact that most of the reservoir bottom was either upon or within a few feet of bed-rock, while a few feet west of the bottom, and immediately underneath the west slope, was found a bed of clay which extended from 12 to 20 ft. below the reservoir bottom. Apparently, this depression in the bed-rock had been the ancient bed of the creek which had been filled by the slide, thus causing the creek to form a new bed further east and upon a higher level. It was expected that, for the first 75 to 100 ft., the tunnel would be in this clay bed and quite a distance above the bed-rock, and it was not known but that secondary lines of movement might be found as low as the bottom of the reservoir; but this did not prove to be the case. For the first few feet a ridge of loose rock, 3 ft. high, was encountered, and after passing this loose rock dike only clay was found until the bed-rock was struck on its upward slope, at a distance of about 200 ft. from the mouth of the tunnel. For the first 70 ft. the tunnel grade rose 2 ft., and from that point the slope was uniform to the bottom of Shaft No. 18, where bed-rock had already been uncovered. While passing through this mass of clay no cracks which gave the slightest indication of any movement at the level of the tunnel were found.

At a distance of 164 ft. from the reservoir, the new tunnel passed under the short tunnel built in 1894 in the rear of the concrete retaining wall. It was in this old tunnel that an old tree stump or log of wood, in a fair state of preservation, was found, at an approximate depth of 40 ft. below the original surface of the ground.

The sewer, for the conveyance of the surface water from the watershed of King ravine into the Washington Street sewer, to which reference has already been made, consisted of 1 602 ft. of 24-in. terra cotta pipe and 148 ft. of 14-in. cast-iron pipe, a total length of 1 750 ft. Its construction was begun in July and completed early in November, 1901, and cost, for materials and labor, $5 123.

As has been stated, the drainage tunnels were completed in September, 1901, and since that date the only work in connection with the reservoirs has been to make frequent surveys of the lines established to determine the rate of the movement, and also to measure the flow of water from the tunnels.

The range lines established in 1895, when the limits of the slide had not been defined closely, were observed regularly until December, 1899. At that time it was decided to establish a new series of lines covering the ground more thoroughly than had been done heretofore. In pursuance of this plan range lines were marked out, crossing the sliding-land tract from north to south, at intervals of 100 ft. for the entire distance between the reservoirs and the apex of the slide. (See Fig. 6.) Points for observation were established along these lines at intervals of 50 ft., making a total of two hundred and sixty points known to stand upon ground which had been moving. These points were marked by a section of 1 or 1½-in. iron pipe about 20 ins. long, driven flush with the surface of the ground, the top of the pipe being filled with lead in which a tack was driven. Surveys of these range lines have been made at frequent intervals since they were established, and the results of these surveys have been tabulated and plotted upon Plate XII, showing the comparison between the rainfall and the movement of the slide.

In further explanation of this diagram it may be said that the monthly movement during the years 1895 to 1899, inclusive, has been computed from the average of readings taken at fourteen points established along seven of the original range lines, situated within the limits of a central belt, 200 ft. wide, extending from the north end of

DIAGRAM SHOWING RANGE LINES ESTABLISHED IN DECEMBER, 1899, COVERING THE ENTIRE AREA OF MOVING GROUND, AND OBSERVED SINCE THAT DATE.

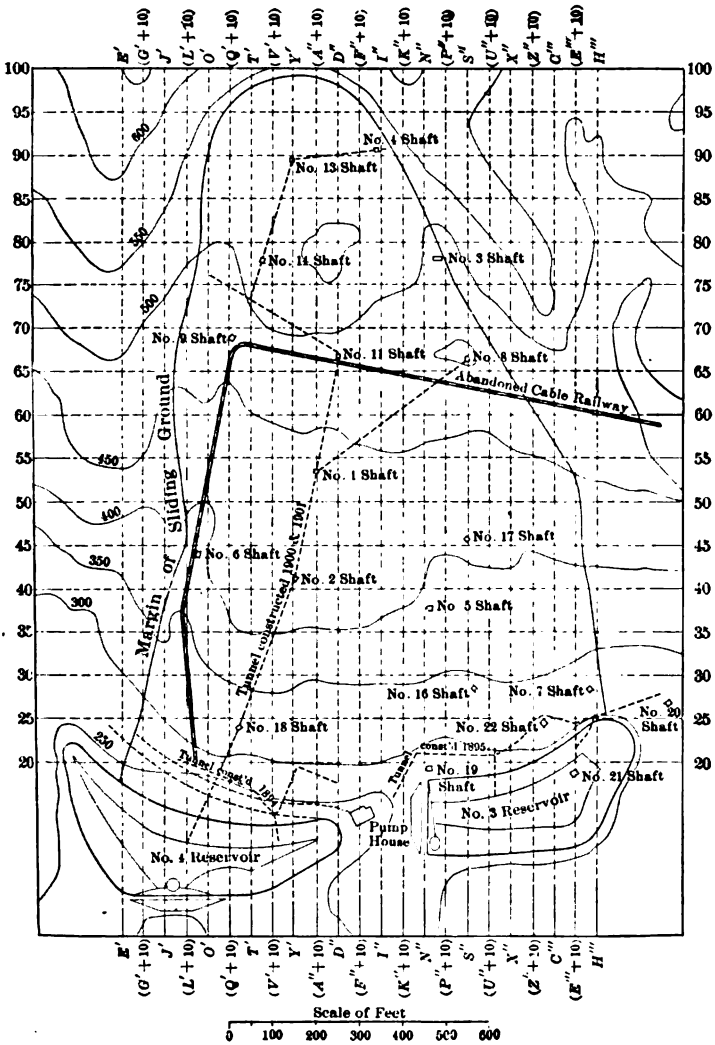


Fig. 6.

Reservoir No. 4 to the center of the "round top," west of Kingston Avenue and the old cable railway. The course of this central belt approximates closely the line of the maximum movement.

The points selected from the surveys made since December, 1899, have been taken from the central belt, and comprise fifty-one stations taken from seventeen of the north and south range lines. (The observations plotted show a movement somewhat in excess of the average of all the points, covering the entire area of the moving ground.)

From a study of Plate XII and other data it is very apparent that the tunnels have been effective in draining away the water pockets and bringing about a condition of stability in the sliding mass. It is also to be noted how closely the decreasing movement of the slide seems to have corresponded with the progress of the tunnel work and the increasing area of drained ground.

The results of the drainage work thus far have been very satisfactory, for during the two years which have elapsed since the tunnels were completed there has been no appreciable movement of the slide. The surveys have shown some slight variations at individual points, from month to month, but these variations have not been confined to one locality and not always to consecutive points upon the same range line. Under the circumstances, it has been thought but fair to assume that the variations noted in the readings at various points have been due in part at least to errors in the instrumental work.

The instrument used in making these surveys since 1897 is a Buff and Berger transit-theodolite, No. 11, purchased expressly for this work. Care has been taken to insure the accuracy of the surveys which have been made from month to month, these having been repeated in whole or in part more than eighty times during the past eight years. As a rule, the readings have been taken from a single transit station at the end of each range line, a plumb-bob string, carefully supported, being used instead of a line rod. In order to be conservative in the matter, it has been considered that a variation of 0.02 ft. between consecutive monthly readings did not necessarily mean that a movement had taken place at any point during any particular month. If successive surveys showed an increasing variation from the original line it was then assumed that there had actually been a movement at that point. The photographs show that the surface of the slide is rough and broken, and hence it will

be seen that a sight at the tack head could not always be taken. It has therefore been assumed that for the purposes of the work 0.02 ft. was not an unreasonable allowance for instrumental error in the survey of the range lines.

The flow of water from the tunnel drains has been observed at frequent intervals since their completion, and the daily flow has been found to range between 10 000 and 15 000 galls. during the summer, and from 25 000 to 50 000 galls. during the winter. After severe rain storms the flow sometimes increases to 75 000 galls. per day for a short time.

The results achieved have been particularly gratifying, for, while the expense of the reclamation work thus far undertaken has been quite large, amounting to more than $31 000 during the years 1895 to 1901, exclusive of the outlay for engineering and superintendence, yet the results accomplished fully justify the course followed by the Water Committee.

The patience of the Water Committee in waiting for the plans of the engineers to be fully developed, and their wisdom and courage in executing these plans so thoroughly after they had been formulated, is especially worthy of mention.

The Committee can now look forward with confidence to the time, not far distant, when the reservoirs can be fully repaired and put into service, thus forming a beautiful and attractive feature of the park system, as well as fulfilling the useful purpose for which they were designed originally. They will thus save, for the use of the City, property which cost originally more than $500 000.

The work of replacing and repairing the broken linings of the reservoirs is yet to be done, and also that of making permanent the tunnel drains. It was at one time planned to begin this work during the year 1903, but, large expenditures being required for extending distribution mains, the reservoir work has been postponed.

Plans are in course of preparation for this repair work, and also for a concrete sewer to be built inside of the drainage tunnel, so as to provide a permanent outlet for all waters percolating through the body of the slide and reaching bed-rock. When this work is accomplished, the "land slide" at the Portland reservoirs will have become an event of the past, and will soon be forgotten by all but those who have been intimately connected with the work.

That the engineers who have been familiar with the details of this work have profited by their experience, is undoubtedly true, and it is with the thought that the lessons taught by the experiences related herein might be helpful to other members of the profession, that the writer has ventured to describe, with a fullness of statement which might not be justifiable under other circumstances, the difficulties encountered and overcome. If the record herein given proves to be helpful to any professional brother, then the purpose of the writer will have been accomplished.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

LATERAL EARTH PRESSURES AND RELATED PHENOMENA.

By E. P. Goodrich, Jun. Am. Soc. C. E.

To be Presented April 20th, 1904.

Introduction.

While theories concerning the action of granular masses, as to planes of rupture and of friction, and as to lateral pressures, etc., are fairly numerous, they are not at all concordant in the results they produce, and these results are not in accord with the few experiments thus far made public, or with common engineering practice in the design of structures having to do with such granular substances. It is hoped that the experiments herein described will throw some light upon the subject, aid designers in getting nearer to the requirements in actual cases, serve to correct some errors in the several theories, and form a nucleus around which to build practicable working rules or perhaps a theory which will indeed agree with fact.

The order of presentation of the following material is almost the opposite of that in which it was worked out.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

WORK OF OTHER OBSERVERS.

An analysis of the data given by Sir Benjamin Baker, in his paper,* "The Actual Lateral Pressure of Earthwork," warrants perhaps one deduction, *viz.*, that the coarser the materials, the less the lateral pressure. The curves of Fig. 1 show that, for coal, shingle, ballast and macadam material, the results are fairly concordant, and that the lateral pressure for such materials is about one-tenth of the vertical pressure, and varies uniformly with it. It appears that the lateral pressure for clay runs often to one-fifth of the vertical pressure, while in loose earth it varies between one-tenth and one-fifth.

The work of G. H. Darwin, described in his paper,† "On the Horizontal Thrust of a Mass of Sand," is of little practical value because of the small size of his model, but several of his conclusions are interesting. He says, "the coefficient of maximum internal friction is probably very different in different parts of a mass of sand," and it is not equal at any point to that of the talus of greatest possible slope, and "is a function of the pressure," and, also, "of the pressure and shaking to which at some previous period the mass of sand has been subjected." Fig. 2 shows the range of his experiments, plotted to a scale for comparison with others.

A. A. Steel, in his article,‡ "Experiments in Earth Pressures against Retaining Walls," concludes, in part, from his work: That the lateral "pressure is not equal to a constant times the head" (vertical pressure); that the surface slope has some slight effect upon the lateral pressure; and that "the nearness of the solid bottom" (of his model) § "has an unknown but large effect on the lateral pressure." His last conclusion is, really, that the compressibility of the earth, combined with its arching effect, affects largely the lateral pressure. The results of his experiments, in terms of vertical and lateral pressures, are shown in Figs. 3, 4 and 5. For dry and moist earth, he finds that the lateral pressure is from one-fifth to one-third of the vertical pressure, and, in saturated materials, is practically equal to it.

The excessively large and the almost minute pressures used by George Wilson, described in his paper,‖ "Some Experiments on Con-

* *Minutes of Proceedings*, Inst. C. E., Vol. LXV, p. 140.

† *Minutes of Proceedings*, Inst. C. E., Vol. LXXI, p. 350.

‡ *Engineering News*, Oct. 19th, 1899, Vol. XLII, p. 261.

§ The words in parentheses are by the writer.

‖ *Minutes of Proceedings*, Inst. C. E., Vol. CXLIX, p. 208.

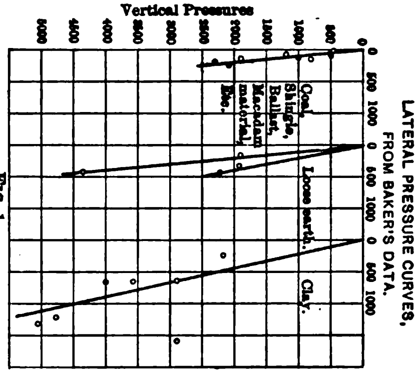


FIG. 1

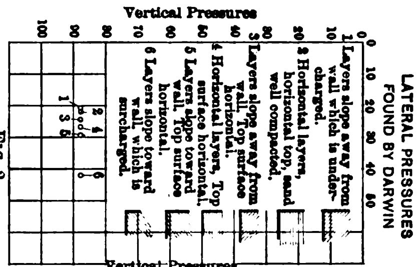


FIG. 2

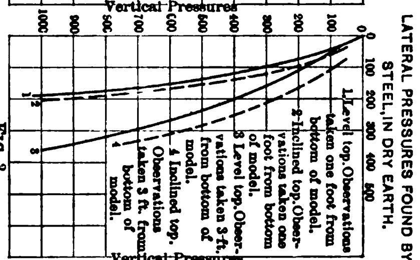


FIG. 3

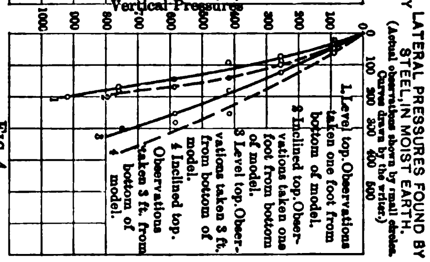


FIG. 4

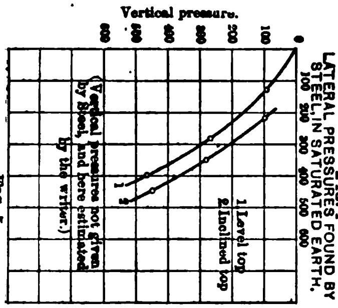


FIG. 5

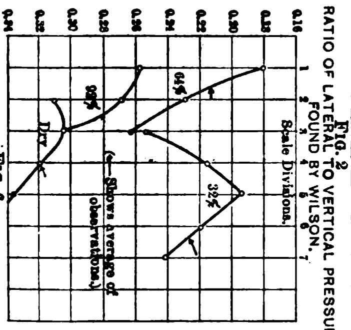


FIG. 6

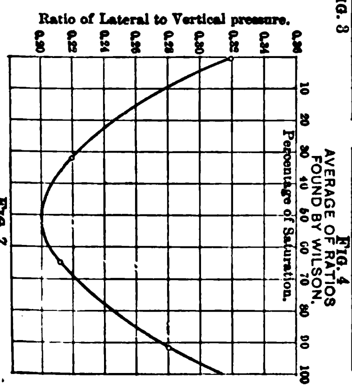


FIG. 7

jugate Pressures in Fine Sand and Their Variation with the Presence of Water," make his work of little value except for comparison. He proves that the tangent of the internal angle of friction, at pressures up to 100 tons, varies with the amount of moisture present. Also, by another series, that, even at depths of a few inches, the moisture present has considerable effect upon the coefficient of friction between sand and metal, sand and glass, and sand and wood. The results of his experiments, replotted for comparison with others, are shown in Figs. 6 and 7. He finds that, with differing amounts of moisture, the lateral pressure at great depths (approximating 1 000 ft.), varies from one-fifth to one-third of the vertical pressure, being—

"Greatest when the sand is dry, or when it is saturated with water; that it diminishes to a minimum between these limits and then increases again; and that the value of this decrement for any particular percentage diminishes as the pressure increases."

Experiments with Model.

One series of observations made by the writer was upon a model which could contain a mass of earth 3 ft. x 3 ft. and 6 ft. deep. (See Fig. 8.) Stiff corner posts were bolted together to make a frame, from which a box could be made by the insertion of removable side-boards 3 ft. long and 1 ft. wide. On one side of the model the boards were fitted with especial care, and paper was placed over all edges so that the particles of earth could not enter the joints and affect the results. About 3 ins. above the center line of the lowest board upon this side, a rod, secured to the vertical posts, was placed so that two bent levers with fulcrums on the rod would each bear with a short arm against the center of the board near its two ends, and so that a long arm would extend horizon-

THREE-FOOT EARTH-PRESSURE MODEL.

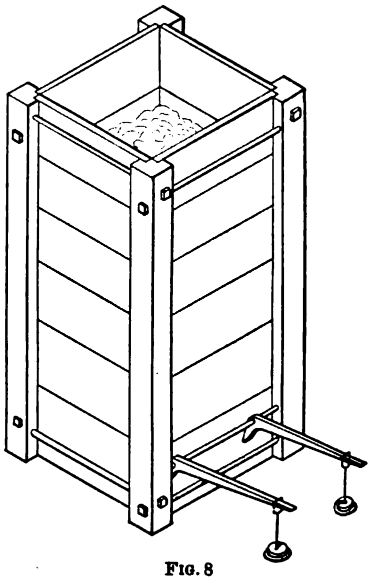


Fig. 8

tally from the model. A scale-pan was arranged to be hung on each horizontal arm, and weights of known values were cast for the pans. Thus, by moving the pans along the horizontal arms, varying pressures of known amounts could be obtained against the board, and, consequently, the lateral pressure of the earth inside the model could be equilibrated. In conducting an experiment, common, slightly moist, bank sand was first thrown into the model to the desired depth. Long, tapering, metal wedges were then inserted between the frame and the lowest movable side-board, and weights were applied to the scale-pans gradually and the latter moved along the lever arms until the wedges dropped by their own weight. The uniformity of the results depended upon the nicety and exact equality with which the wedges were inserted, and this depended entirely upon the skill of the observer. After a little practice, enough skill was acquired so that the results of the observations made on separate days did not differ more than could be attributed to other sources of variation, such as the manner of depositing the sand in the model, its varying humidity, etc. Furthermore, two consecutive series of observations by any individual observer did not vary more than 10%, including all sources of error.

CURVE OF LATERAL PRESSURE FOR MOIST SAND, FOUND BY THE WRITER'S MODEL.

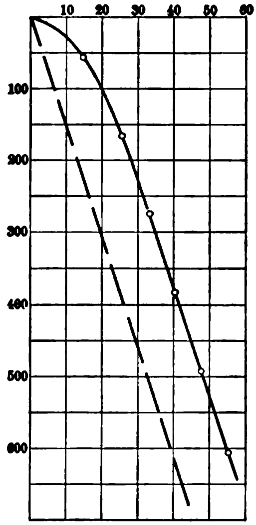


FIG. 9

Fig. 9 gives the averages of all results obtained with the apparatus shown in Fig. 8. In this experiment the lateral pressure is approximately one-fifteenth of the vertical pressure plus 15 lbs., thus being less than one-fifth of the vertical pressure, except near the surface, and diminishing with increased vertical pressures. The curvature of the upper portion of the figure shows the same departure from uniform variation found by Steel (see especially Figs. 3 and 5). The 15-lb. constant would immediately suggest a uniform friction increment or arch-action increment, and, doubtless, there were such increments, because of the small size and of the manner of construction of the model. The small ratio of lateral to vertical pressure also indicates such conditions, and the results, therefore, are believed to be of little value.

Experiments with Retaining Wall.

Another experiment was tried, in connection with the filling behind a line of sheet-piling driven to form the face of a retaining wall. A section of the piling was selected which was fairly straight and had been evenly driven. A box, 6 x 1 x 15 ft., inside measurement (see Fig. 10), was constructed without a top and with the sheath-piling as one of the large sides. This brought the other large side of the box broadside to the fill. This side consisted of 3 x 10-in. yellow pine plank, 15 ft. long, and was, therefore, of such material and dimensions as to permit of appreciable deflection by the lateral pressure of the fill. As the box was well braced around the ends, and the top was left open, a measuring instrument could be dropped down inside of the box to ascertain the distance between the sheet-piling and the deflected side at various depths. This device consisted of a long, square rod which was marked off in 1-ft. lengths. At the lower end of the rod, and at right angles to it, was fastened a 1 x 3-in. strip slightly longer than the smallest inside dimension of the box. The end of the rod was at the center of the strip. This was duplicated exactly by a second piece, arranged so as to slide on the rod, which second piece always remained at the top of the box. By this arrangement, the top piece would always show the exact angular position of the bottom one, in whatever position the rod was twisted. By lowering the rod by degrees into the box in a fixed vertical line, and twisting it at each depth so that the bottom piece was "brought up" with its two ends against the two inner sides of the box, the slide at the top would give the exact angle of the bottom piece. Moreover, if one corresponding end of the slide was brought in contact with one side of the box, at the top, the distance from the other end of the slide to the other side

DIAGRAM OF ARRANGEMENTS IN RETAINING-WALL EXPERIMENTS.

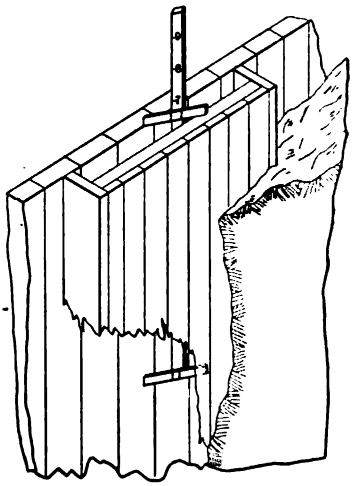
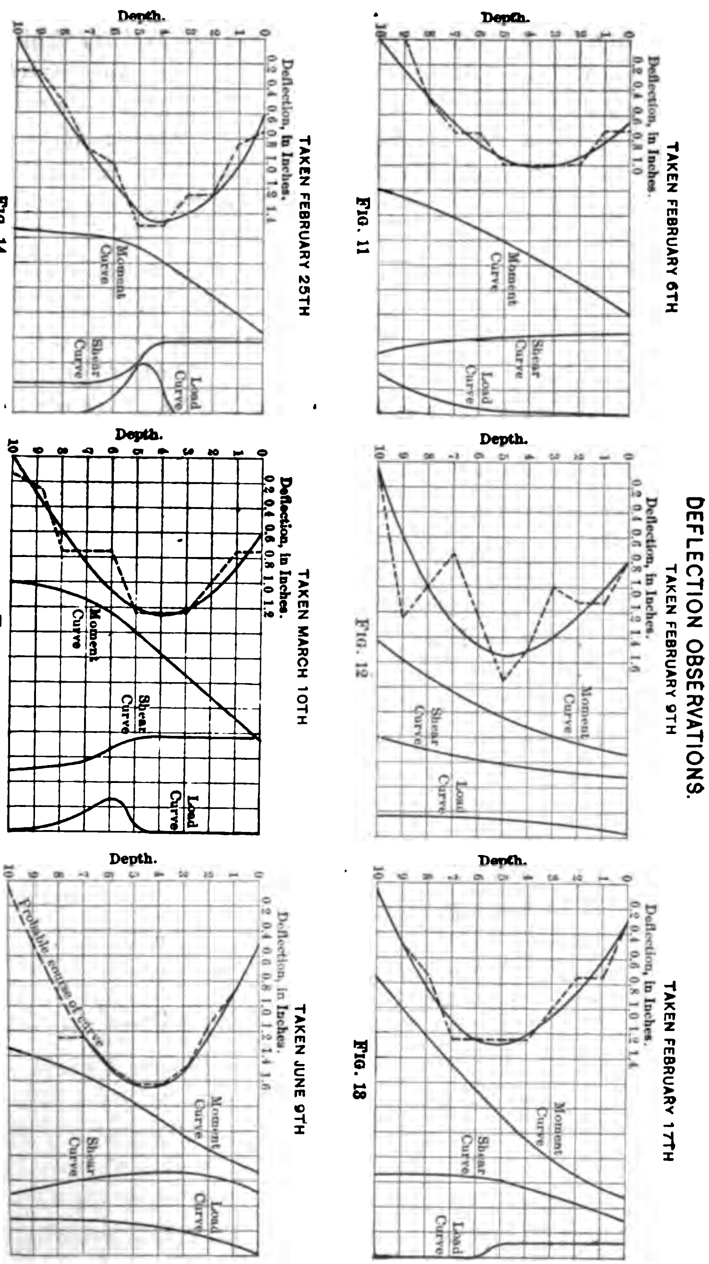


Fig. 10

DEFLECTION OBSERVATIONS.



TAKEN FEBRUARY 6TH — FIG. 11

TAKEN FEBRUARY 9TH — FIG. 12

TAKEN FEBRUARY 17TH — FIG. 13

TAKEN FEBRUARY 25TH — FIG. 14

TAKEN MARCH 10TH — FIG. 15

TAKEN JUNE 9TH — FIG. 16

of the box would equal the difference in the breadth of the box between that at the top and that at the point of observation. This difference was the measurement sought, being the deflection caused by the earth pressure at the point observed. Readings were taken in this manner, (*a*) before any earth was in contact with the box, (*b*) as soon as it had been brought half way up the box, (*c*) as soon as the fill was completed, and (*d*) after varying intervals of time. The deflection curves are shown at the left of Figs. 11 to 16.

The filling consisted of earth excavated during freezing weather, and the fill was made by dumping on the edge of an embankment. Thus, the material immediately against the box at the time of the first two observations was principally frozen lumps. The third observation was taken after a thaw of several days, and the remaining ones after the frost had entirely left the ground.

It was desirable to obtain some analysis of the deflection curves, in order to see whether they would show in any way how the pressure obtained its full effect in deflecting the timber, and whether different conditions of the filling material caused any variation in pressure. The actual observations, therefore, were plotted for each series (shown by the dashed lines at the left of Figs. 11 to 16), and approximate deflection curves (shown in full lines) drawn through them. A curve in which each ordinate of one curve is proportional to the difference between two corresponding consecutive ordinates of another is the first differential of the latter curve. In Fig. 17, let $a\ b\ c$ be the given curve, in which y_1 and y_2 are any two consecutive ordinates, all of which are spaced uniformly.

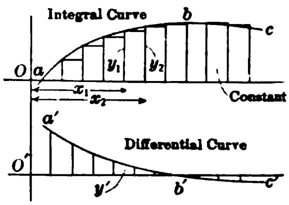


FIG. 17

By construction, make $y^1 = m\ (y_2 - y_1)$.

Then $$y^1 = n\,\frac{(y_2 - y_1)}{\text{constant}} = n\,\frac{(y_2 - y_1)}{(x_2 - x_1)} = (\text{at limit})\ \frac{d\,y}{d\,x}.$$

Hence, having drawn the deflection curve, the moment curve can be drawn by laying off equally spaced ordinates along the deflection curve and constructing a second curve in which similarly spaced ordinates are proportional to the difference between the consecutive ordinates of the first curve. Similarly, a shear curve can be drawn from the moment curve, since the shear is the first differential of the

moment at any point. The same rule applies to constructing the load curve from the shear curve, but, for a somewhat different reason. In Fig. 18, let $a\,b\,c$ be the shear curve, in which y_1, y_2 are any two consecutive ordinates, all of which are spaced equally. By construction, make $y^1 = m\ (y_1 - y_2)$.

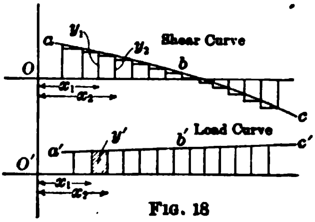


FIG. 18

Then $y^1 = n\ (y_1 - y_2) \div$ (constant) $= n\ (y_1 - y_2) \div$ (space passed over) $= n\ (y_1 - y_2) \div (x_1 - x_2)$.

Therefore, $y^1\ (x_1 - x_2)\frac{1}{n} = y_1 - y_2$. But, $y^1\ (x_1 - x_2) =$ area between the curve and the axis, which represents the load passed over. Consequently, the first curve is a shear curve for the second curve as a load curve; and conversely.

Moment, shear, and load-line curves were constructed in this way from the approximate deflection curves observed, and the load curves thus obtained afforded in some crude manner the information sought.

That the load is over only the lower half of the box, is shown by Fig. 11, and its practically uniform variation is revealed. Fig. 12 shows that immediately after the fill was completed the pressure extended throughout the full height of the box, and tends to show its approximately uniform variation. Furthermore, it has the slight curve near the surface found by Steel (see Fig. 5), and by the writer in his first-described experiment (see Fig. 9). The thaw which occurred between the second and third observations appears to have loosened the surface materials and to have brought into play an increased pressure at the lower levels (see Fig. 13). A week later the point of greatest pressure seems to have worked downward (Fig. 14), and, after another interval, appears to have dropped lower still (Fig. 15). In each of these three observations the local pressure was sufficient to relieve the plank from all strains, except in close proximity to the maximum point. After a final interval of three months, the load curve seems to have resumed its normal shape (Fig. 16), *i. e.*, practically uniformly varying. (Compare Figs. 12 and 16.) Of course, these deductions could be only qualitative in nature, but they do not appear abnormal, and are interesting in that they disclose in some measure the phenomena which take place during the gradual settle-

ment into place of a mass of earth against a retaining wall, which deflects as the load increases.

In order to ascertain to some extent the amount of the pressure exerted by the earth in the observed cases, a 3 x 10-in. plank was supported at points 10 ft. apart and loaded with brick arranged so as to form a triangular pile with the apex over one support. The loading was continued, as shown in Plate XIV, until the observed deflection equalled that formed in the earth-pressure observations. The weight of the brick thus piled was 2 580 lbs., which would be equivalent to a little more than 3 000 lbs. per foot of width of the earth. On the assumption of uniformly varying distribution, this gives a pressure of 600 lbs. per square foot at a depth of 10 ft. For various reasons, this seems to be excessive, and it is improbable that the actual pressure was more than 500 lbs. The material which made up the fill was principally fine beach sand which weighed about 100 lbs. per cubic foot in its final compact condition. This would show a lateral pressure approximately one-half of the vertical at the depths tested. This is large when compared with the observations thus far described, but, perhaps, may be accounted for partly by the action of the tide water, which was separated from the earth only by the 6-in. sheet-piling which formed one side of the experimental box.

In a similar manner, an attempt was made to ascertain the lateral pressure exerted by rip-rap under water. In this case, the pile of stone was 7 ft. deep and came only to a point 7 ft. from the top of the box. A deflection of $\frac{7}{8}$ in. was observed, and the weight of the brick necessary to produce an equal deflection under a uniformly varying load covering an equivalent portion of a 3 x 10-in. plank, 14 ft. long, was 452 lbs. This would mean a lateral pressure of about 150 lbs. at a depth of 7 ft. As the rip-rap (which was practically cobble stone) weighed about 140 lbs. per cubic foot in air, this would indicate a lateral pressure of slightly more than one-seventh of the weight in air, or, taking sea water at 64 lbs. per cubic foot, of nearly 30% under water. It is to be noted, on the other hand, as a fact within the writer's experience, that triangular piles of rip-rap about 14 ft. high readily withstand the thrust of a mass of earth 24 ft. in height above the same base (Fig. 19). On the assumption that the earth weighed 100 lbs. per cubic foot and gave a lateral thrust of one-

FIG. 19

PLATE XIV.
PAPERS, AM. SOC. C. E.
MARCH, 1904.
GOODRICH ON LATERAL EARTH PRESSURE
AND RELATED PHENOMENA.

METHOD OF DETERMINING THE PRESSURE AND DEFLECTION IN SHEET-PILING.

half the load at any point, the total lateral pressure would be 28 800 lbs. On the further assumption that all this thrust was equilibrated by the rip-rap in such a manner that its lateral thrust varied uniformly (which is a forced assumption), the maximum value of this thrust would be 514 lbs. per square foot, found at a depth of 14 ft. Much rip-rap does not weigh more than 1 ton per cubic yard, or about 83 lbs. per cubic foot. Under water this would have an effective weight of only about 20 lbs. A pile 14 ft. high would exert a vertical pressure of 280 lbs. at its base. This amount readily withstands a lateral thrust of 514 lbs. Thus, while the least ratio, according to Moseley's principle, was 1 to 7 for the rip-rap tested, the greatest ratio may be almost 2 to 1.

Experiments with Testing Machine.

Description of Apparatus.—This actual value of the ratio of the lateral pressure to the vertical pressure is the important item in all questions involving earth pressure, and almost all queries concerning this subject can be answered satisfactorily when this ratio is known.

Several devices were constructed by the writer to measure this ratio directly, but, with one exception, without success.

It is an easy matter to provide and measure a vertical pressure upon a mass of earth, but, in order to measure the corresponding lateral pressure, some measuring instrument must be devised which will register the pressure and at the same time allow of no deformation under this pressure, for, the instant such a movement occurs, the internal conditions are altered and the results are rendered untrustworthy. An arching of the material will take place across any relatively small opening formed in the side walls of a containing vessel, so that the results usually obtained, when experiments are made with such an apparatus, do not show the true lateral resistance offered before the opening was made. It is well known that the pressures found against the valves of coal pockets and grain elevators are but a small fraction of those found against the entire sides of the pockets and bins.

An apparatus, Fig. 20, was finally devised which, it was believed, would provide against these difficulties. A cast-iron cylinder was bored out to a diameter of 6 ins. and a depth of 5 ins. It had a strong base and walls, and a plunger was fitted to it, which was arranged so

that it could be secured to the head of an ordinary testing machine. A 1-in. hole was bored in one side of the cylinder near the bottom, and a plug was carefully fitted to the hole. The outside of the cylinder was faced where the hole was bored, and the plug was made with a circular head, the underside of which was carefully turned to set accurately upon the planed portion of the outside of the cylinder. The plug was just long enough to reach through the wall of the cylinder and be flush with its inner face. The faced portion of the outside of the cylinder was slotted horizontally opposite the center of the 1-in. hole, and hard-rubber insulation was carefully fitted in the slots. Upon these hard-rubber pieces, thin strips of copper were secured and constructed so that they could be connected to the terminals of an electric battery. In the circuit with the battery was also placed an

CYLINDER FOR DETERMINATION OF RATIO
OF LATERAL AND VERTICAL PRESSURES.

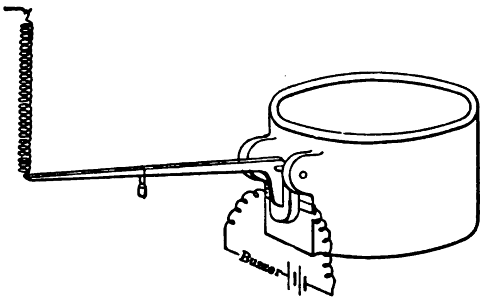


FIG. 20

ordinary buzzer. When the plug was fitted to the hole and pushed home, the underside of its head touched the copper strips on each side and thereby completed an electric circuit, the sounding of the buzzer giving evidence of the fact. If the plug was pushed slightly outward the circuit was broken and the buzzer stopped. Experiment showed that a movement of but $\frac{1}{1000}$ in. was sufficient to break the circuit, and that the tone given out by the buzzer was so sensitive that movements approximating $\frac{1}{5000}$ in. could be detected easily. With movements of the lateral weighing mechanism no greater than these, it is believed that no internal changes can take place which affect internal stresses sufficiently to vitiate the results obtained.

The cylinder was cast with two lugs upon the outside, just above the plug hole, and in such a position that holes bored through the

lugs held a bolt which served as a fulcrum for a bent lever. One of the arms of the lever was horizontal and was marked somewhat like a steelyard. The other arm bore against the head of the plug. Weights of various sizes were arranged so as to be hung on the horizontal arm and be moved along it as might be desired. The weight of the lever was neutralized by means of a spring attached to the free end of the horizontal arm and adjusted so that it relieved the head of the plug from all initial pressure.

Method of Experimentation.—In conducting an experiment, the cylinder was filled, with the material to be tested, to a point slightly above the inner end of the plug, and placed upon the bed of a testing machine. The plunger was then adjusted under the head of the machine and brought down gradually upon the material in the cylinder. About the time that contact between the disc and the material was expected, the buzzer was put in operation and gave forth a continuous sound, until the lateral pressure against the inner end of the plug was sufficient to push it out slightly and break the circuit. The increasing application of the vertical pressure was then stopped and the location and value of the weights upon the horizontal lever arm were noted. The lateral pressure against the head of the plug was then carefully increased, by changes in the location and amounts of weights on the horizontal arm, until this external lateral pressure was just sufficient to press the plug back to its original position and thus restore the electric circuit and start the buzzer. The testing machine was then again started, and the vertical pressure increased until the internal lateral pressure was sufficient to move the plug outward and stop the buzzer, thus completing a cycle of operations. This series was repeated until any desired limit of vertical pressure had been reached. Usually, after such an increasing series had been executed, the reverse operation was followed through, as the machine was being brought back to a zero reading. This showed the difference in the action of the material, in regard to its lateral thrust, during increase and decrease of vertical load.

It was only after considerable experiment that the above-described method of procedure was decided upon. The lower curve of Fig. 21 shows a typical series of results obtained by it. For comparison, there are also shown in the upper curve the results secured when the load on the testing machine was reduced each time, so as to start the

buzzer again after each new increment of pressure had been brought to bear on the head of the plug, and the vertical pressure had been worked up to the point of stopping the buzzer. Asterisks show where a new weight was placed on the horizontal lever arm, and are the points at which breaks in the curve would be expected to occur, if they are to occur at all. In all that follows, the curves given and described are those formed by using the first of the above-described methods, and only the increasing series of readings are treated, unless expressly stated to the contrary.

Discussion of Results.—While many questions arise, concerning the reliability of the results obtained and their proper interpretation, several points seem to be brought out fairly well by the observations.

The effect of repeated applications of pressure without loosening up the earth between such repetitions is shown in Fig. 22. It is to be observed that in dry materials the curves usually remain practically straight lines, differing only in slope and always starting from zero. In moist earths the first application of pressure, also, usually gave a straight line, but a peculiar permanent set sometimes seemed to be encountered in succeeding applications of pressure during their earlier portions. This is revealed clearly by the curve which forms the upper part of the line of pressure, in the 30–50 sand observation. It starts from zero, but attains the direction of its later movement only by a reversed curve. This starting curve shows that, in some instances, after the first application of vertical pressure, lateral pressures may exist which are larger than the corresponding vertical ones. (See Fig. 23, which shows the second application of pressure on 30–50 sand at 31% of saturation.) This only serves to confirm the observations made by Darwin with his model, that previous treatment, and, in his case, the direction of even slight stratification, affects materially the amount of the lateral pressure. This peculiar action of moist earth is of interest to designers of quay walls, dock walls, dock bulkheads, dry-dock walls, etc., who have to deal with cases where excessive loads must be borne occasionally. In general, however, when the earth is not touched between successive applications of pressure, the change of slope of the lines is such that the actual lateral pressure, up to a certain limit, is slightly less with each successive application. This is in conformity with the observed

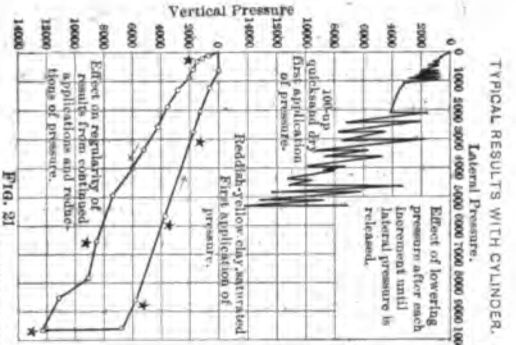


FIG. 21

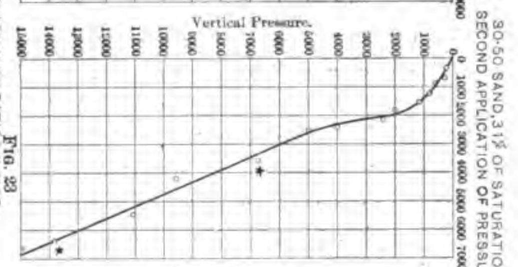


FIG. 23

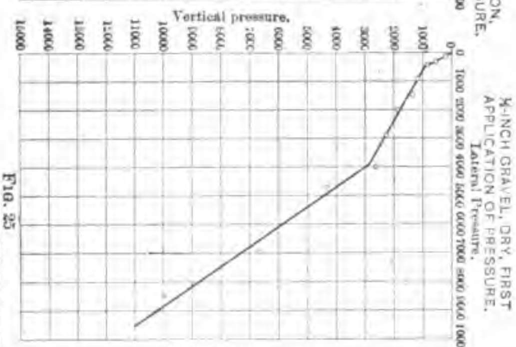


FIG. 25

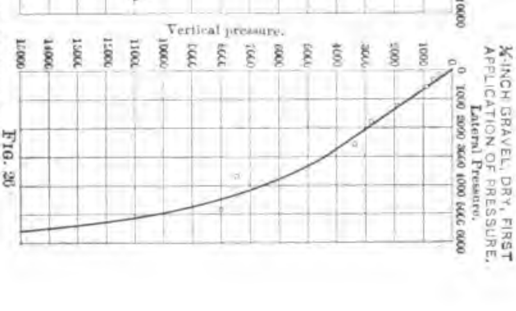


FIG. 26

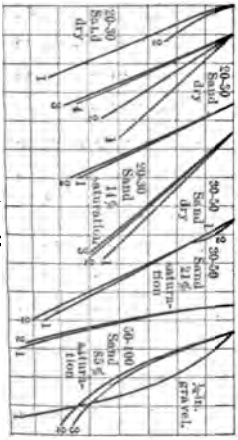


FIG. 22

CURVES SHOWING RELATION OF RATIOS UNDER REPEATED APPLICATIONS OF PRESSURE.

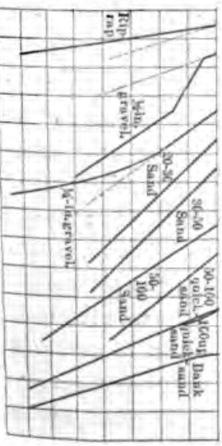


FIG. 24

CURVES SHOWING RELATIVE RATIOS FOR DRY MATERIAL

fact that freshly made fills behind retaining walls seem to exert greater lateral pressure than they exert after an interval of time. Of course, this effect of diminished pressure may also be caused by a gradual drying out of the fill, and sometimes by other causes, but it is probable that repeated applications of heavy loads, also, have some effect. The tests of dry materials, which differed only in the size of the particles, seem to reveal a singular increase and then a decrease of the ratio of lateral to vertical pressure. The maximum ratio is found with 30–50 sand; that is, with sand consisting of particles which pass through a sieve having 30 meshes per linear inch, or 900 per square inch, and are held on one having 50 meshes per linear inch, or 2 500 per square inch. (See Fig. 24.)

The erratic nature of the curves for ½-in. and ¼-in. gravel (Figs. 25 and 26), show primarily that the size of the individual grains was too large for the special mechanism used to test them. If, however, the first three observations for ½-in. gravel and the general trend of the results for ¼-in. gravel are used for comparative purposes, a most interesting compound curve is developed. (See Fig. 27, where observations on rip-rap, made by the writer, are also included for wider comparison.) With very coarse particles, such as rip-rap and coal, the ratio is small, but increases as the materials grow smaller, through ½-in. and ¼-in. gravel, to the coarsest sand. When the particles range in size from those which will just pass a sieve with 20 meshes to the inch to those which will just be held by a sieve with 50 meshes to the inch, the ratio reaches a maximum. As the particles diminish in size still further, whether they are uniform or vary so that the mass contains large and small grains, with an appreciable percentage of the latter, the ratio diminishes. In Fig. 27 are plotted the ratios observed at 6 000 lbs. per square foot vertical pressure, for all the sizes of grains tested. The curve thus formed seems to start from zero and increase rapidly to a maximum, then diminish and, finally, with a change in curvature, go out to infinity along one axis as an asymptote. This makes a curve astonishingly like the lituus shown in the same figure, but no relation is apparent between the equation of the lituus and the conditions involved in this problem. A little consideration, however, shows that this curve does represent about what is to be expected. In masses formed of very large pieces there is usually little lateral pressure, and when the number of particles per inch ap-

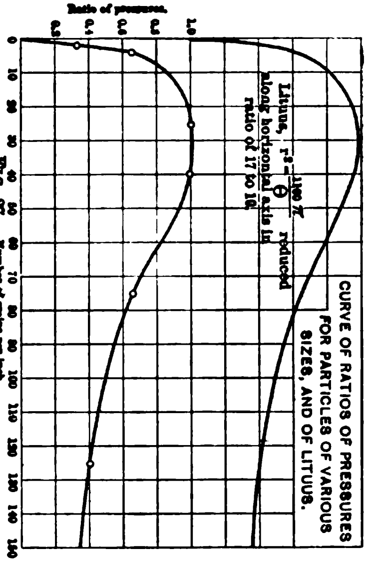


FIG. 27

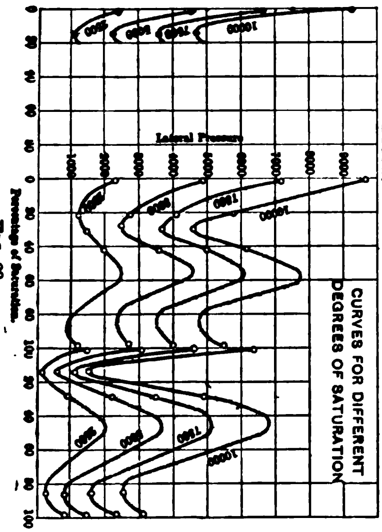


FIG. 28

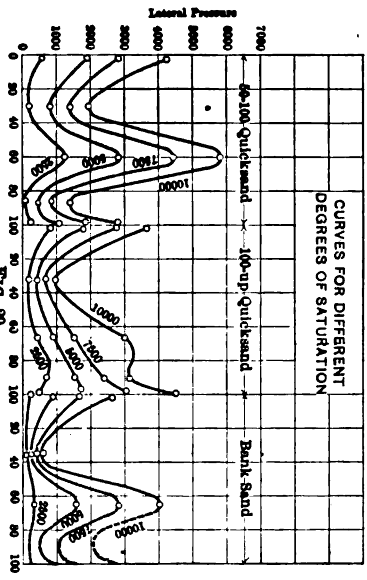


FIG. 29

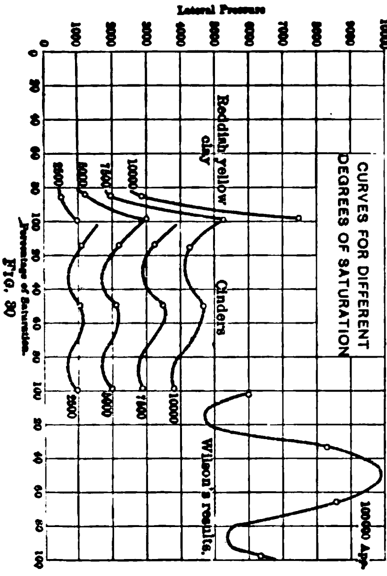


FIG. 30

proaches zero, that is, when the pieces combine in a single block of stone, the lateral pressure, of course, is zero. It is evident, at the other extreme, that, as the size of the granules grows smaller until they become microscopic, constantly increasing cohesive molecular forces will come into play, so that, with particles of molecular dimensions, the mass has become again one solid block through cohesion, and can exert no lateral pressure of the variety studied herein.

Concerning the effect of moisture upon the ratio of lateral to vertical pressure, an even more surprising phenomenon is observed. See Figs. 28, 29, and 30. For each class of material, four curves or parts of curves are there shown, which represent the lateral pressures observed at different percentages of saturation, under vertical pressures of 2 500, 5 000, 7 500 and 10 000 lbs. per square foot. Beginning with the lowest one and counting upward, the curves are for these pressures, respectively. In these diagrams the actual observations made are shown by the small circles. The full-line curves show the probable course of the phenomena between the actual observations, while the dashed lines show the possible remaining portions of these curves, as the writer believes they would be. While not absolutely proven, the results seem to indicate that, in all the cases tested, a curve similar to the one for 50–100 quicksand is to be expected, and that the latter may be considered as a typical one. In this curve are to be found two minima and one maximum. Starting with a given ratio for dry sand, the ratio decreases at first with increasing saturation, then increases sometimes beyond the starting value, only to decrease again nearly as low as in the first minimum, and finally to increase up to a final medium value. This is not quite in accord with the curve given by Wilson, but his observations covered only two percentages of saturation aside from the dry and practically saturated, so that it is still possible that a curve of the form found by the writer may be drawn through the values found by him. This is shown in the diagram at the right of Fig. 30.

These curves for varying percentages of moisture may be represented by equations of the form,

$$y = a + b\,x + c\,x^2 + d\,x^3 + e\,x^4,$$

in which the coefficients may be determined for any given set of observations, but such determinations are tedious and the resulting quantities indicate nothing as to the questions naturally arising. The

equation which will give practically the curve for 50–100 quicksand under a pressure of 10 000 lbs. per square foot (see the upper left-hand curve in Fig. 29), is

$$y = 0.00001056\,x^4 - 0.016754\,x^3 + 1.4056\,x^2 + 16.28\,x + 42,$$

in terms of hundreds of pounds vertical pressure, measured along the axis of y, and percentages of saturation, along the axis of x.

Why the equation should be of this form is not obvious, but a possible explanation of the shape of this typical curve may be made. It is well known that with slight additions of moisture the cohesion between the particles of earth is increased greatly, and hence the ratio of vertical to lateral pressure would probably decrease down to some limit. (See Fig. 31.)

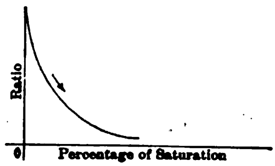


FIG. 31

It is well known, however, that, long before the moisture would fill all the voids, some change takes place to reduce the cohesion and hence increase the ratio of vertical to lateral pressure. (See Fig. 32.) At the other extreme, it is well known that considerable water makes an excellent lubricant between polished surfaces of stone, and that the friction increases with decrease of water. As the friction would increase, the cohesion would increase and the ratio of the vertical to the lateral pressure would decrease. (See Fig. 33.) Experience, however, teaches that when the amount of moisture is very small, the friction is also small and, similarly, the ratio of vertical to lateral pressure would be relatively larger. (See Fig. 34.) The curves produced by these two causes might coincide, for aught one can see,

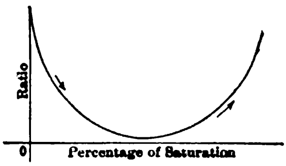


FIG. 32

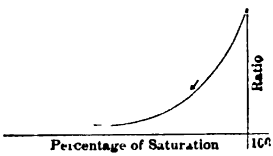


FIG. 33.

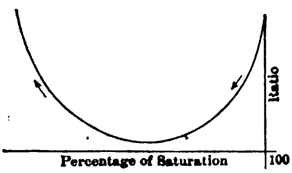


FIG. 34

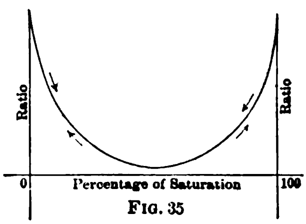


FIG. 35

but the experiments seem to show that they do not, but form the double curve actually observed. (See Figs. 35 and 36.) Inspection of the various saturation curves, further, shows that the effect of the moisture is more marked under heavy vertical pressures than under lesser ones.

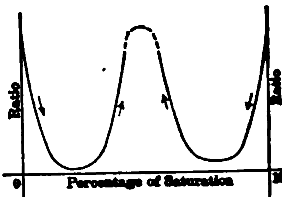


FIG. 36

The large ratios found for 20–30 and 30–50 sand are suprising, and would be open to more doubt, but for the singular regularity of the curve of Fig. 27. Perhaps, however, this is only an accident. Comparison of the curves for 50–100 bank sand and 50–100 quicksand reveals great similarity, and suggests that it is the fine particles only of quicksand which give it its peculiar qualities. The curves for 100–up quicksand do not show a well-marked second minimum, but do show a fairly constant increase of lateral pressure, up to saturation. At this saturation point, the lateral pressure is larger than for materials of any other size, except the surprising 30–50 sand and the clay. Experience would lead one to expect a relatively high lateral pressure for the latter material, especially when saturated. But, in the quicksand, even with the relatively high lateral pressures at saturation, they do not approach nearer than about 50% of the vertical ones when the water of saturation is confined with the sand, as occurred in the model during the test, and these lateral pressures are much less when the water is drained away to some extent, that is, when the sand is not saturated. Therefore, it would seem that those designers who are using a ratio of one (a "hydrostatic" ratio) in designing retaining walls where quicksand is encountered are using excessive assumptions. Apparently, at least in part, the peculiar nature of quicksand inheres in its extreme fineness. More than 80% of the sample from the Brooklyn Navy Yard tested by the writer passed a standard No. 100 sieve. This property makes it practically impossible to confine it. It will flow, when saturated, wherever water does. Furthermore, it is doubtful if the large pressures sometimes attributed to quicksand are really more than those actually produced by the water saturating the sand. The problem of the designer, dealing with quicksand, is only, then, to impound completely the water which the sand contains, and in accomplishing this he need deal with no pressures except the hydrostatic ones.

TABLE No. 1.—AVERAGE RATIOS FOR VARIOUS MATERIALS AND PRESSURES.

Kind of material.	Observer.	Average Ratio of Vertical to Lateral Pressure.				Variation from Average Ratio of— Maximum probable value.				Minimum probable value.				Remarks.
		2 500 lbs.	5 000 lbs.	7 500 lbs.	10 000 lbs.	2 500 lbs.	5 000 lbs.	7 500 lbs.	10 000 lbs.	2 500 lbs.	5 000 lbs.	7 500 lbs.	10 000 lbs.	
		Ratio.	Ratio.	Ratio.	Ratio.	Percentage.	Percentage.	Percentage.	Percentage.	Percentage.	Percentage.	Percentage.	Percentage.	
Coal, shingle, ballast, macadam materials	Baker	0.10	......	......	......	6	......	......	......	4	......	......	......	
Rip-rap (under water)	Goodrich	0.15	......	......	......	......	......	......	......	......	......	......	......	
½-in. gravel	"	0.41	......	......	......	......	......	......	......	......	......	......	......	Observations incomplete.
¼-in. gravel	"	......	......	......	0.50	......	......	......	......	......	......	......	......	Observations incomplete.
Hard-coal cinders	"	0.40	0.42	0.44	0.44	4	2	5	2	0	4	4	6	
20-30 sand	"	0.72	0.71	0.72	0.71	......	......	......	......	23	25	24	24	Observations incomplete.
30-50 sand	"	0.60	0.60	0.60	0.60	......	......	......	......	12	10	11	14	Observations incomplete.
50-100 sand	"	0.36	0.40	0.40	0.40	......	......	......	......	32	28	25	24	Observations incomplete.
50-100 quicksand	"	0.24	0.26	0.30	0.32	34	32	26	16	10	14	22	28	
100-up "	"	0.20	0.22	0.25	0.28	12	14	14	18	12	10	16	17	
Bank sand	"	0.10	0.18	0.24	0.25	2	14	18	15	2	12	18	19	
Earth	Steel	0.26	......	......	......	10	......	......	......	10	......	......	......	
"	Baker	0.15	......	......	......	5	......	......	......	5	......	......	......	
Bank sand	Wilson	......	......	......	0.26	......	......	......	10	......	......	......	10	
" "	Goodrich	0.33	......	......	......	......	......	......	......	......	......	......	......	With friction apparatus.
" "	"	0.50	......	......	......	......	......	......	......	......	......	......	......	Against retaining wall.
Clay	"	0.40	0.40	0.40	0.40	20	20	30	36	......	......	......	......	Observations incomplete.
"	Baker	0.22	......	......	......	35	......	......	......	10	......	......	......	

The high lateral pressures found in absolutely dry sand made up of coarse grains are of no importance to designers, as such materials are never encountered in practical experience, and no materials are found in a loose, dry state. Whenever earth dries out completely, the particles are cemented together into a fairly rigid mass by the evaporation of the moisture which the earth contained and the deposition of the solids which were held in solution in it. It then exerts little lateral pressure, or none at all.

With the usual factors of safety for engineering structures, it is not necessary to allow for the maximum lateral pressures observed for any kind of material, but a selected average value can be used without dangerous error. Such an average, when selected carefully, will give results within the range of variation due to other causes. Table No. 1 shows such values, collated from all the foregoing data, and also shows the percentage which the maximum and the minimum probable values will differ from this average.

The observations of the writer upon his 3-ft. model with bank sand are omitted purposely, as the results, evidently, were influenced by the small size of the model. It is doubtful whether models less than 6 or 10 ft. in least dimension will ever afford trustworthy results, except with perfectly dry materials.

The ratio found for rip-rap by the writer agrees fairly well with the ratio deduced from Baker's paper for materials of somewhat similar character. The values for gravel and cinders also have fair uniformity. The unexplained decrease of the ratio with increased fineness of material is again noticeable in Table No. 1, as well as the facts that, with coarse materials, the ratio is practically constant, whatever the pressure, and that when the material is fine in texture it increases with the pressure. Perhaps the latter fact can be explained partly by the increased compressibility of the finer materials, and, consequently, the increased internal friction which would be expected when the particles were close together.

The low ratios of 0.10 and 0.07, for bank sand, found by the writer, with the cylinder and the model, do not accord well with those of 0.26, 0.33 and 0.50 found by Steel for earth and Wilson for sand, and by the writer for bank sand in the retaining-wall experiments. The values of 0.07, 0.10, 0.15, 0.26, 0.33 and 0.50, made up of those mentioned, together with one of Baker's for earth, show conclusively, however, that

a general average cannot be determined which will not be subject to a possible 50% error, and that for a close design one must examine carefully the kind of material, and ascertain, as well, its degree of saturation and its previous treatment. After the determination of these points, reference would best be made to the curves of Figs. 28, 29, and 30. Baker's maximum ratio for clay is practically the same as the writer's minimum, and, because of the character of the observations, the agreement can be said to be good.

For almost all purposes, the ratios in the column headed 2 500 lbs. will be the ones to be used, because, with earths of common density, such a pressure would be found at depths of about 25 ft.

From the data in Table No. 1, it is evident that a ratio of 40 : 100 is ample for all but exceptional cases, and that, where conditions can be regulated, a ratio of still smaller size can be used. The actual relation which the use of this ratio bears to common practice is shown clearly by Fig. 37.

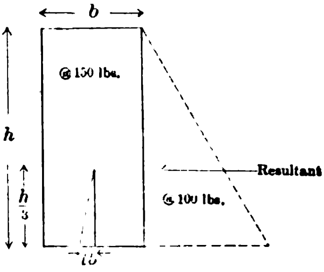


FIG. 37

Let a wall h feet high and b feet thick, weighing 150 lbs. per cubic foot, be made to support a uniformly varying earth pressure wherein the lateral thrust is four-tenths of the vertical. Let this be due simply to the weight of the earth, which is taken at 100 lbs. per cubic foot. The usual rule is followed, of applying the resultant lateral thrust at one-third the height of the wall from its base, and of allowing the resultant of the pressures to cut the base at the edge of its "middle third."

Then, lateral pressure $= \frac{4}{10} \times \frac{100\,h}{2} \times h = 20\,h^2$;

Total weight of wall $= 150\,b\,h$.

Then, $$20\,h^2 : 150\,b\,h :: \frac{1}{6}\,b : \frac{1}{3}\,h,$$

$$\frac{20}{3}\,h^3 = \frac{150}{6}\,b^2\,h,$$

$$4\,h^2 = 15\,b^2,$$

$$b = h\sqrt{\frac{4}{15}} = 0.484\,h = \frac{h}{2}\text{, approximately.}$$

Trautwine* gives 0.5 as the relative thickness for walls of "well-scabbled dry rubble," with ratios of 0.4 and 0.35 of the height for breadth of walls of "good common scabbled mortar-rubble, or brick" and of "cut-stone, or of first-class large ranged rubble, in mortar," respectively. These ratios tend to show that common practice either does not limit the resultant to the "middle third," or assumes a ratio of lateral to vertical pressure less than 0.4.

The lateral pressures obtained by Steel, and several of the writer's results, show a departure from uniform variation of which a few authorities try to take account. Where the curves are straight lines starting from zero, the resultant would be applied, theoretically, at a point one-third of the height of the plane of pressure above its bottom. Where the curves are concave upward, as in the second and third applications of load to the ½-in. gravel, and the first observations on 20–30 sand (see Fig. 22), the resultant would be found below the one-third point. This condition is rarely met, and may be neglected. In many cases, however, the curve is convex upward, and the resultant would actually be located above the one-third point. This is on the danger side, if the common rule is followed, of basing computations on the assumption of its being applied at the one-third point. While the reliability of the curves here shown is rather small, in many cases, still an investigation of them along this line will prove of interest. In the following-named curves, the location of the resultant is as indicated:

Figure.	Fraction of height above bottom at which resultant is applied.
3	0.40
4	0.39
5	0.38
9	0.38
12	0.40
16	0.39

This would tend to show that a much safer practice would be to assume that the resultant is applied at a point four-tenths of the height from the bottom, in place of one-third, as is usually done at present. The difference between these two assumptions involves the stability of structures to the extent of 20 per cent.

* Engineer's Pocket-Book, 18th ed., p. 608.

Internal Friction Angle.

According to Rankine*, the ratio of the vertical and lateral pressures is expressed by the ratio

$$\frac{1 - \sin.\ \phi}{1 + \sin.\ \phi},$$

in which ϕ is the limiting angle of internal friction at any point. If the ratio is known, the angle can be computed from the formula

$$\sin.\ \phi = \frac{1 - r}{1 + r}.$$

Having found the sine of the angle, its tangent can be found easily in any table of natural functions.

Table No. 1 shows that the ratio varies with the pressure, in many cases, and, consequently, the limiting angle of friction must vary accordingly. Similarly, this limiting angle of internal friction is certain to differ in most cases from that of the angle of the natural slope of the free surface of the material.

This angle of slope was determined carefully for bank sand of varying percentages of saturation, by dropping it carefully from a given height (of a few inches) so that it would form a cone, and then measuring the altitude and average diameter of the base of this cone, and computing the tangent of the angle of surface slope. The results thus obtained are shown in the curve at the left of Fig. 38. For purposes of comparison, the tangent of the limiting angles of internal friction, in the case of 50–100 quicksand, were computed from the formula, and in the manner described above, and are shown in the other curves of Fig. 38. It is somewhat surprising to find the same type of curve with a maximum and two minima in the case of the surface angle, but its nature is evident and also its general similarity to the curves of the computed tangents.

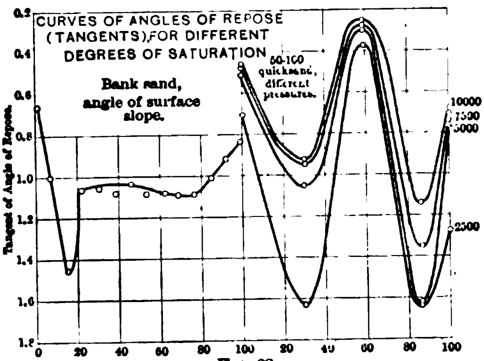


Fig. 38

* Civil Engineering, 19th ed., p. 819.

The actual surface slope of the bank sand tested, in connection with the retaining wall, was also found on the occasion of a slip which occurred. The slope under water was 1 to 2, and above water level 1 to 1. The surface slopes of the samples of cinders, gravel, etc., experimented with were also determined, and are given later.

A series of experiments was also carried out to determine the actual tangent of the limiting angle of internal friction for various earths. That it varies with the pressure, is shown readily by constructing two boxes without tops and of the same dimensions except the depths, which must differ. Fill both with sand and put one above the other with the open tops together, then tilt the under one until the upper one just slides, and then repeat the operation with the boxes reversed. A marked difference in the angle of sliding will be observed with damp sand, even with boxes but 2 and 3 ins. deep.

Quantitative experiments of this character were carried out by building two boxes, 1 ft. in each internal dimension, but without tops and only one with a bottom. (See Fig. 39.) The latter box was fastened to the edge of a high platform and had a pulley attached to it, and arranged so that a line would lead from the other box when placed on top of the first, over the pulley to a scale-pan upon which known weights could be placed. The two boxes were placed in position, and the weight which would just move the upper one over the fixed one when empty was ascertained. The coefficient of friction of the pulley was also determined for different loads, and the results were used to correct the later observations.

MODEL FOR DETERMINATION OF COEFFICIENT OF INTERNAL FRICTION.

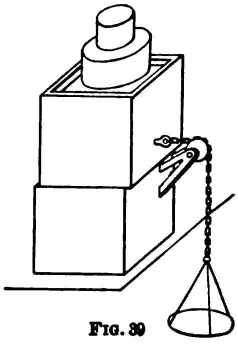


FIG. 39

In conducting an experiment, the two boxes were filled with the earth to be tested and enough weights added to the scale-pan to start the upper box to sliding. It was then checked and jacked back into position and a loose top placed on the upper surface of the earth and known weights piled on this top. Weights were then added to the scale-pan until sliding again just took place. This operation was repeated with increasing weights on the earth, until, for various practical reasons, it became impossible to carry the operation farther.

Fig. 40 gives the actual results obtained, and, for comparison with previous results, Fig. 41 shows the results of the observations reduced so as to give the lateral pressures for various loads. The writer's observations with the 3-ft. model are inserted, for further comparison. Figs. 42, 43, 44 show the relation between the lateral pressures computed from the friction experiments and those observed directly with the cylinder. They show conclusively that Rankine's theory of conjugate pressures is correct when the proper angle of friction is used.

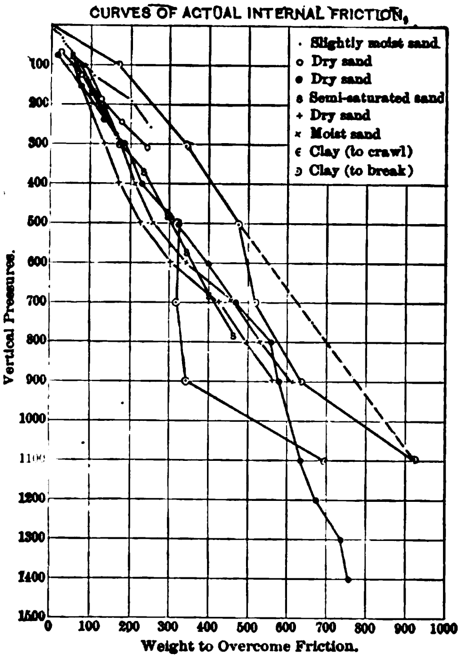


FIG. 40

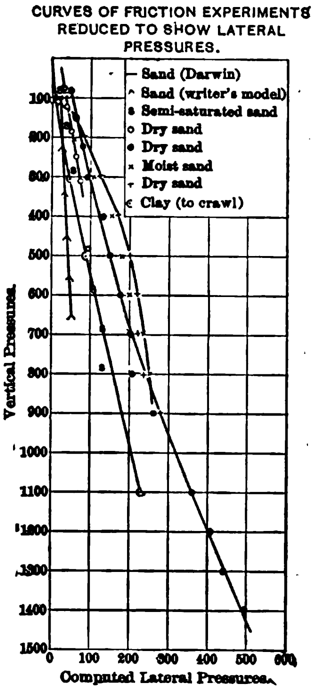


FIG. 41.

The relation between the angle of surface slope and the angle of internal friction in one instance is shown in Fig. 45. The dashes show the possible connecting curves between those of the internal friction angles and the points locating the tangents of angles of surface slope. It would appear from this figure, and from the curves of Figs. 42, 43, and 44, that some relation exists between the angles of surface slope and of internal friction. This relation is shown in Fig. 46, where the dry-sand curve of Fig. 45, slightly altered, is repro-

duced. (Curve A.) Both curves of Fig. 45 are also drawn to one-tenth the horizontal scale there shown, with further observations inserted. (Curves B and C.) It is also again drawn to one one-hundredth of that scale horizontally, with still further observations inserted. (Curve

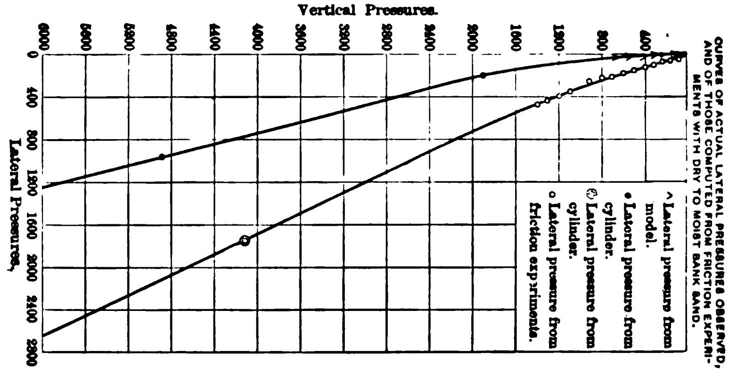


FIG. 42

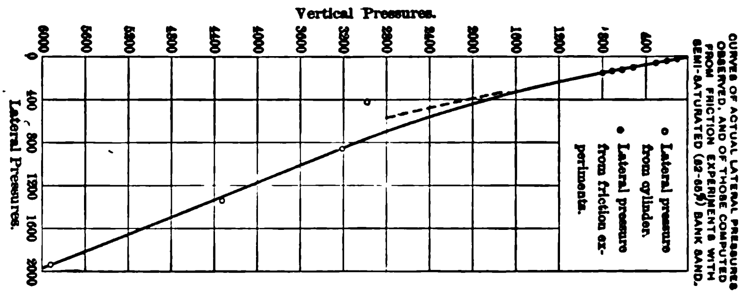


FIG. 43

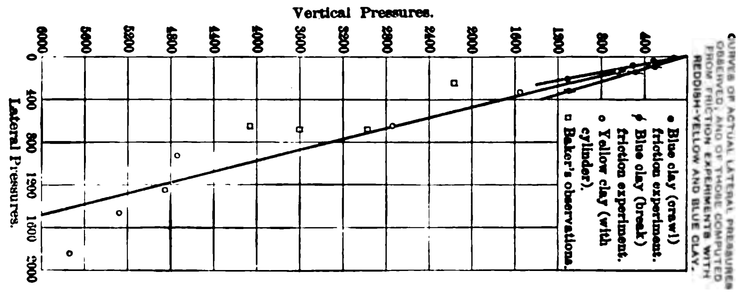


FIG. 44

D.) For all practical purposes, the curve may be considered as a nearly straight line composed of the right-hand main portion of the curve, and the dotted curve connecting the starting point with this main portion. The sharp drop to the minimum is of no consequence,

as it occurs in the first foot or two of depth. In this special case, for depths down to about 6 ft., the tangent of the angle of internal friction may be considered as that of the angle of surface slope. Below

CURVES SHOWING TANGENTS OF ANGLES OF SURFACE SLOPE AND OF INTERNAL FRICTION ANGLES NEAR SURFACE.

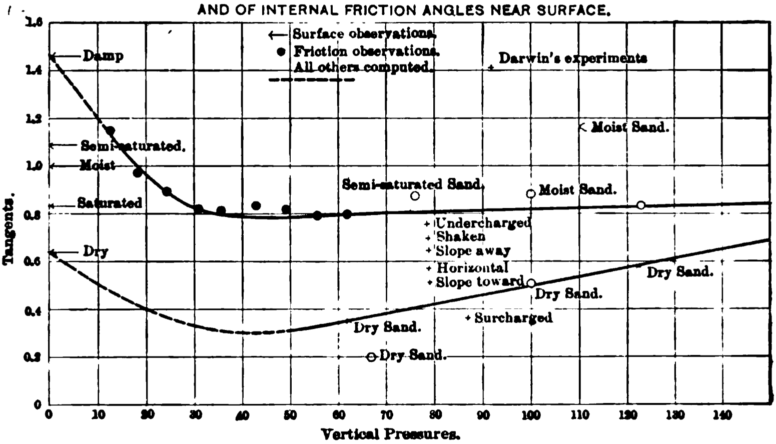


FIG. 45

CURVES SHOWING TANGENTS OF ANGLES OF INTERNAL FRICTION.

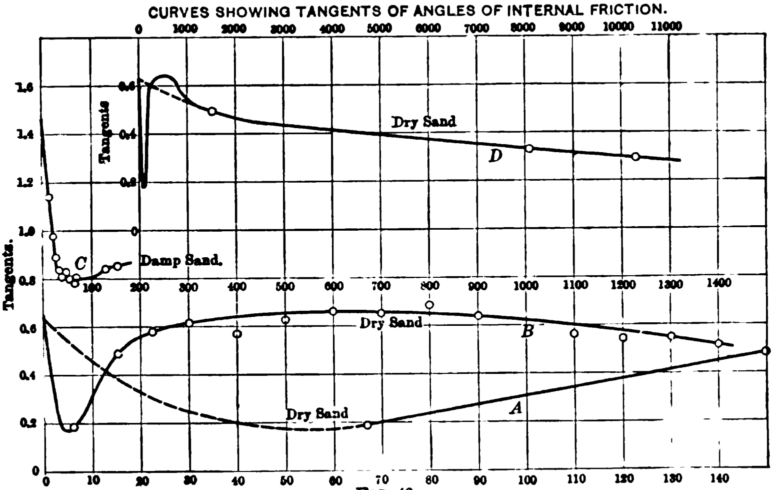


FIG. 46

6 ft., however, the angle of internal friction falls off, at first rapidly, then more and more slowly. The determination of an analytical curve of similar shape can be of no practical value, as will be shown directly.

TABLE No. 2—ANGLES OF INTERNAL FRICTION AND OF SURFACE SLOPE FOR DIFFERENT MATERIALS.

Ratio of lateral to vertical pressure.	Kind of material.	Observer.	Tangent of angle of internal friction.	Tangent of angle of surface slope.	Observer.
Percentage.					
10	Coal, shingle, ballast, etc.	Baker	1.428	1.11 to 0.70	Rankine.
				1.45 " 0.60	Goodrich.
	Bank sand	Goodrich	1.428	1.00 " 0.67	Trautwine.
				0.75 " 0.38	Rankine.
15	Rip-rap	Goodrich	1.097	1.00	Goodrich.
	Earth	Baker	1.097	0.66	Trautwine.
20	100-up quicksand	Goodrich	0.895	....	....
	Clay	Baker	0.895	1.00	Rankine.
25	50-100 quicksand	Goodrich	0.750	....	....
	Earth	Steel	0.750	0.66	Trautwine.
				0.58	Steel.
	Bank sand	Wilson	0.750	0.58 to 0.62	Wilson.
30	....	....	0.622	....	....
35	50-100 sand	Goodrich	0.549	0.85	Goodrich.
	Bank sand	"	0.549	0.75 to 0.88	Rankine.
40	Clay	"	0.474	1.00	Rankine.
	Cinders	"	0.474	0.86	Goodrich.
	⅛-in. gravel	"	0.474	0 66	Trautwine.
50	¼-in. gravel	"	0.350	0.85	Goodrich.
	Bank sand	"	0.350	0.75 to 0.88	Rankine.
60	30-50 sand	"	0.258	0.66	Goodrich.
70	20-30 sand	"	0.179	0.75 to 0.88	Rankine.

Table No. 2 gives various ratios of lateral to vertical pressure, the materials with which the experiments were made, and the computed tangent of the limiting angle of internal friction. The tangents of angles of usual surface slope are also included, but the relation between these two angles is shown more clearly in Fig. 47.

DIAGRAM SHOWING RELATION OF TANGENTS OF ANGLES OF SURFACE SLOPE AND OF INTERNAL FRICTION.

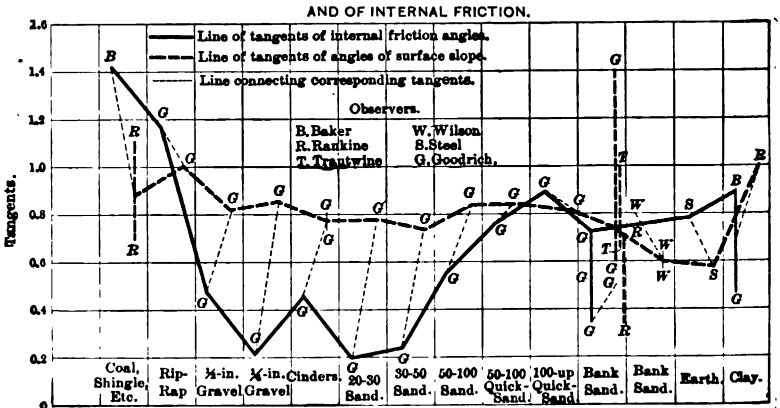


FIG. 47

With the exception of rip-rap and clay (the particles of the one being perhaps too large and of the other too small), all the surface slopes tend toward such as have tangents between 0.50 and 1.00, irrespective of the angles of internal friction. This would tend to prove that practically the same laws of rolling friction exist for materials of different-sized particles and degrees of saturation, while the laws of internal friction depend more intimately upon, and vary with, the size of the particles and the percentage of their saturation. Consequently, designers must look to the angle of internal friction and not to that of the surface slope to furnish them with data for their computations. These vary considerably, under different circumstances, and no general rule can be laid down.

Compressibility of Soils.

Tests of the compressibility of various soils were also made, but they revealed only the facts: (*a*) that the layers immediately beneath the compressing disc were much more compressed than the more distant ones; (*b*) that a sort of compressed cone formed under the compressing disc; (*c*) that an appreciable percentage of compression took place only with excessive loads which would correspond to great depths below the surface; (*d*) that, under extreme pressures, garden earth and sand showed quite an elastic reaction, the former showing the more, and (*e*) that clay, even when showing but a small quantity of water present, would "crawl" and relieve the pressure by squeezing through the smallest openings in long threads or sheets.

Recapitulation.

More experimental data of a practical variety should be secured, as the subject of pressures in earth is one upon which the whole scientific design of the foundations of engineering structures depends.

It is believed that the scientist can work along the lines described herein with a more or less clear perception of the following facts or conclusions, herein first deduced, or here brought out in confirmation of what experience has already taught:

1.—Repeated applications of pressure to earths in general develop diminishing lateral reactions.

2.—In moist earths the first large application of pressure is likely to produce a permanent set which exerts excessive lateral thrusts at low repetitions of pressure.

3.—The lateral thrust in dry materials which differ only in size of particle varies as the ordinates to a lituus.

4.—The lateral thrust, in materials which differ only in the percentage of saturation, varies as the ordinates to a curve of the fourth degree, possessing two minima and one maximum between 0 and 100% of saturation.

5.—Some explanation of the lituus curve may be obtained from the relation of molecular forces to the size of the granules.

6.—Some explanation of the curve of the fourth degree may be obtained from the phenomena of adhesion between water and particles of earth, together with capillary action, and of the friction between two faces of rock with water as a lubricator.

7.—The effect of moisture is more marked at heavy vertical pressures than at lesser ones.

8.—The peculiar nature of quicksand inheres, in part at least, in the size of its particles, and the curves of the fine portion do not possess the maximum to be found with particles of larger sizes.

9.—Clay, which possesses still smaller particles, has a higher relative lateral thrust, but, because of its nature, does not "flow," but "crawls."

10.—Earth-pressure experiments, to be of practical value, must be on models of large size, because of the effect of arching action.

11.—The effect of increase of pressure is more apparent in materials of small particles. Perhaps this is because of increased internal friction. The greater compressibility of fine materials results in a relatively large decrease in the distance between particles and thus in increased friction.

12.—In many cases the resultant of the pressures on a plane should be applied at a point above the lower one-third point.

13.—Rankine's theory of conjugate pressures is correct, when the proper angle of friction is found, and probably adaptations of his formulas will be of most practical value.

14.—The coefficient of rolling friction of particles of different sizes is practically constant, irrespective of size and of amount of moisture present.

15.—The limiting angle of internal friction depends upon the size of the particles and the degree of saturation of the material.

16.—In the loading of earth, a cone of compressed material forms under the compressing body.

17.—Earths, under certain conditions, reveal elasticity.

For the practical engineer and the designer of structures, the following points are deemed pertinent:

18.—The lateral thrust of newly made fills against retaining walls decreases with time and repeated applications of the load.

19.—With some moist earths, a heavy load will induce in the material a possibility of the development of excessive lateral thrusts under repetitions of even relatively small loads.

20.—Neither saturated nor loose dry materials are apt to exert the greatest lateral thrust, and, with slight saturation and rather moist conditions, the lateral thrust is apt to be relatively small.

21.—When dealing with quicksand, the problem is to confine the water which it contains, and account need be taken of pure hydrostatic pressures only.

22.—When dealing with clay, the problem is to remove the water which it contains and guard against the creeping of the material under excessive loads.

23.—In many cases the resultant of the lateral pressures on a plane should be applied at a point fourth-tenths of its height above the bottom.

24.—Angles of internal friction and not of surface slope must be used in all formulas which involve the sliding of earth over earth. Such angles, or the ratio from which they may be computed, are given in the writer's tables and curves.

Acknowledgment is due, especially, to Mr. W. L. Sturges, A. I. E. E., for interest and assistance in securing data for the materials herein contained, and to the Brooklyn Polytechnic Institute for the use of its testing machine.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

LAKE CHEESMAN DAM AND RESERVOIR.

By Charles L. Harrison, M. Am. Soc. C. E., and
Silas H. Woodard, Assoc. M. Am. Soc. C. E.

To be Presented May 4th, 1904.

Part I.
HISTORY, DESIGN AND CONSTRUCTION.

By Charles L. Harrison, M. Am. Soc. C. E.

The City of Denver, Colorado, with a population of about 150 000, is supplied with water by The Denver Union Water Company, a corporation which was formed in 1894 by the consolidation of the Citizens Water Company and the American Water-Works Company, both of which had previously been furnishing water to the city and to private consumers.

General Conditions.

Denver is situated about 15 miles from the eastern foothills of the Rocky Mountains, in what is known as the semi-arid region of the West. The elevation of low water in the South Platte River, at

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Fifteenth Street, is 5 194 ft. above mean sea level, and the higher portions of the city are from 200 to 300 ft. above this.

The precipitation is much less than in the Middle and Eastern States, averaging for the past 32 years only 13.87 ins. Outside of the mountain region, this is principally in the form of rain, but during the winter there is considerable snow, which remains on the ground but a short time. Table No. 1 gives the monthly and yearly precipitation, from 1872 to 1903. The minimum was 8.48 ins., in 1893, and the maximum 21.43 ins., in 1891, or more than two and one-half times the minimum. In May, 1876, the precipitation was 8.57 ins., and in April, 1900, it was 8.24 ins., or about the same as for the entire year of 1893. In April, 1900, it was greater than for the other eleven months of that year.

TABLE No. 1.—RECORD OF PRECIPITATION AT DENVER, COLORADO, IN INCHES.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1872	0.55	0.22	0.91	2.09	3.74	2.07	2.69	1.75	1.57	0.68	0.69	0.29	17.25
1873	0.13	0.24	0.22	2.43	0.75	2.24	2.00	1.41	0.89	0.73	0.16	0.61	11.81
1874	0.84	0.53	0.49	1.70	2.43	1.21	3.35	0.68	1.34	0.64	0.08	0.17	13.46
1875	0.38	0.60	0.39	2.24	1.94	0.43	4.17	1.97	2.89	0.22	1.28	0.59	17.10
1876	0.21	0.11	1.80	1.22	8.57	1.10	1.16	2.03	0.60	0.12	1.50	1.70	20.12
1877	1.90	0.40	1.40	2.77	2.30	1.93	0.33	1.30	0.38	2.15	0.73	0.77	16.36
1878	0.10	0.48	1.82	0.05	2.90	2.78	1.33	2.25	1.23	0.80	0.67	1.05	15.46
1879	0.40	0.39	1.00	2.62	3.36	0.32	0.64	1.38	0.02	0.19	0.21	0.33	10.86
1880	0.38	0.32	0.21	0.31	1.11	1.22	1.38	1.46	0.89	1.37	0.83	0.10	9.58
1881	0.50	1.22	0.87	0.50	2.21	0.09	2.50	2.33	0.57	0.32	1.68	0.00	12.79
1882	0.57	0.20	0.20	1.47	2.98	4.96	0.66	1.20	0.06	0.75	0.71	0.73	14.49
1883	2.35	0.45	0.21	3.10	4.30	0.85	2.27	0.75	1.08	1.49	0.32	2.32	19.49
1884	0.22	0.86	0.93	3.33	4.61	1.47	0.65	1.71	0.13	0.21	0.19	0.76	15.07
1885	0.41	0.75	0.97	4.94	2.13	0.66	1.33	1.18	1.22	0.73	0.55	1.08	15.95
1886	0.62	0.72	2.36	2.79	0.09	2.26	0.50	1.62	0.98	0.33	1.93	0.87	15.07
1887	0.67	0.30	0.23	2.16	1.13	0.53	2.49	2.68	0.97	0.97	0.22	0.14	12.49
1888	0.11	0.37	1.15	1.71	2.66	0.29	0.41	1.51	0.11	0.77	0.33	0.09	9.51
1889	0.50	0.70	0.40	1.34	3.44	1.88	2.94	0.33	0.28	2.11	0.53	0.30	14.75
1890	0.18	0.46	0.35	2.50	2.01	Tr.	0.79	1.89	0.17	0.64	0.30	0.04	9.33
1891	1.60	0.27	3.10	2.49	4.15	2.93	0.59	2.84	0.73	0.48	0.69	1.56	21.43
1892	0.40	0.75	1.20	1.75	2.14	1.33	1.19	0.58	Tr.	3.92	0.44	1.32	15.02
1893	0.05	0.83	0.23	0.87	3.09	0.13	1.14	0.35	0.05	0.84	0.55	0.35	8.48
1894	0.18	0.90	0.70	3.30	3.00	0.39	2.11	1.86	1.55	0.19	0.22	0.69	15.09
1895	0.32	0.48	1.19	1.19	2.86	2.65	4.28	0.76	0.98	1.13	0.27	0.01	16.12
1896	0.25	0.24	1.43	0.93	1.27	0.89	2.80	0.97	1.81	0.84	0.10	0.31	11.84
1897	0.58	0.82	0.90	1.31	3.15	2.16	2.06	1.44	0.44	1.64	0.24	0.63	15.37
1898	0.20	0.68	0.28	1.20	4.88	0.94	0.67	0.96	0.28	1.05	0.85	0.99	12.98
1899	0.65	0.58	1.10	0.75	0.15	0.47	1.92	1.78	0.20	1.01	Tr.	0.72	9.33
1900	0.13	0.55	0.63	8.24	0.53	1.87	1.30	0.05	0.87	0.33	0.37	0.42	15.29
1901	0.05	0.06	0.88	1.96	1.18	2.09	0.01	1.30	0.22	0.46	Tr.	0.89	9.10
1902	0.17	0.38	0.63	0.60	1.98	1.89	1.24	0.76	3.70	0.80	0.61	0.59	13.35
1903	0.12	0.42	0.87	0.81	0.75	1.62	1.36	1.35	0.56	1.34	0.07	0.23	9.50
Aver. for 32 years.	0.49	0.51	0.91	2.02	2.56	1.42	1.64	1.39	0.84	0.91	0.54	0.64	13.87

The South Platte River, which flows through Denver, has its source in the Rocky Mountains and, with its tributaries, drains an area above the city of 3 910 sq. miles. About 2 900 sq. miles of this area are in the mountain region and 1 010 sq. miles in the prairies below the foothills. Of the tributaries in the latter area, Bear Creek and Cherry Creek are the only ones which furnish a water supply of any importance.

In the mountain region tributary to the South Platte River, the precipitation is largely in the form of snow, which falls and accumulates from November to April, and melts during May, June and July. The greatest floods in the river occur during these three months, and the magnitude of the floods is in proportion to the amount of accumulated snow in the mountains. During the remainder of the year there are showers and occasional cloud bursts of great violence, but they usually cover small areas and very seldom produce a flood in the river of any considerable extent or duration. Generally, the high-water period is less than two months in length while the low-water period covers the remainder of the year.

Sources of Supply.

The only source of a sufficient supply of water for Denver is the South Platte River and its tributaries. The ranchmen also draw on these streams for irrigation water. Under existing climatic conditions, the lands will produce very little without irrigation, but with it they become marvelously productive. It is not surprising, therefore, that the ordinary flow of the streams is already over-appropriated by the ranchmen and the water company, so that any increased supply must be secured by storing the flood waters.

The Company secures water from the following sources (see Fig. 1):

1.—Cherry Creek, at Sullivan, where underground cribs are built in the sand and gravel. The water reaches them by infiltration and flows by gravity through a 36-in. pipe to the Capitol Hill Reservoir, from which it is pumped to one of the high-service districts of the city.

2.—In Denver, at Mississippi Street, near the South Platte River, where water is gathered in underground cribs and flows by gravity in a 48-in. wooden pipe to the West Side Reservoir and is then pumped into the distributing mains.

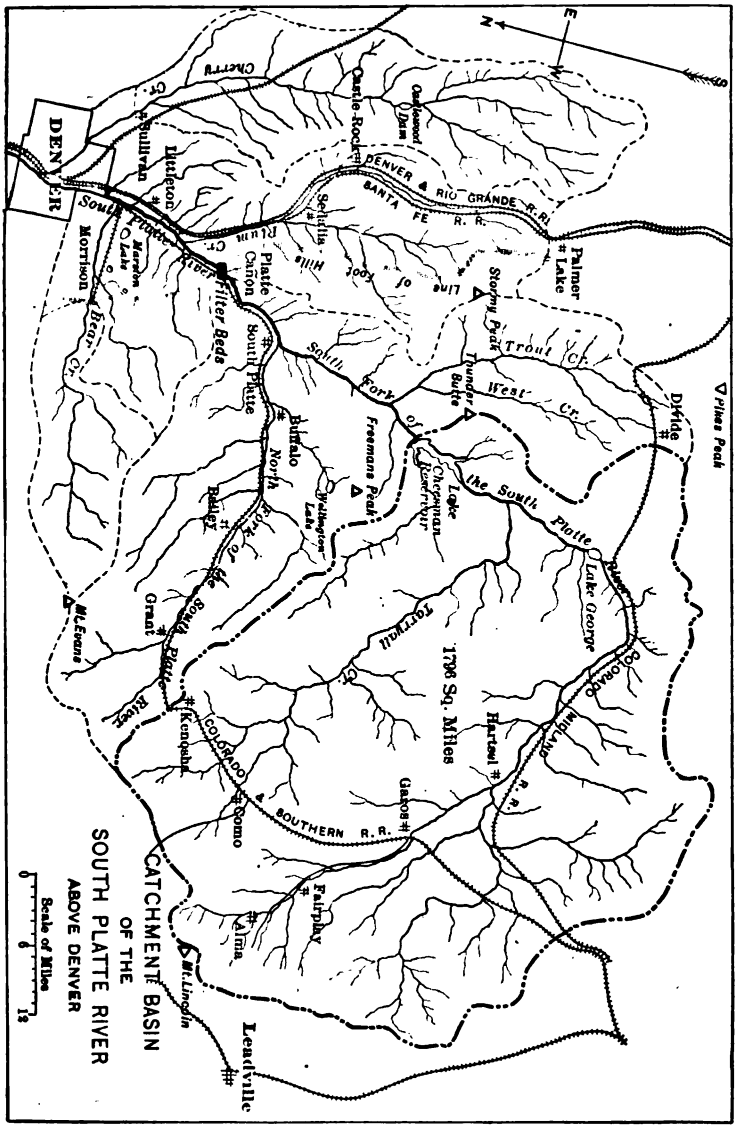

CATCHMENT BASIN
OF THE
SOUTH PLATTE RIVER
ABOVE DENVER
Scale of Miles
0 6 12
1796 Sq. Miles
DENVER
DENVER & RIO GRANDE R.R.
SANTA FE R. R.
COLORADO & SOUTHERN R. R.
COLORADO MIDLAND R. R.
Castle-Rock
Sullivan
Littleton
Morrison
Platte Cañon
Filter Beds
South Platte
Buffalo
Palmer Lake
Stormy Peak
Thunder Butte
Divide
Pikes Peak
Lake Cheesman Reservoir
Freemans Peak
Wellington Lake
Lake George
Bailey
Grant
Mt. Evans
Kenosha
Como
Garos
Hartsel
Fairplay
Alma
Mt. Lincoln
Leadville
Trout Cr.
West Cr.
Tarryall Cr.
Bear Cr.
Cherry Cr.
South Fork of the South Platte River
North Fork of the South Platte River

FIG. 1

3.—At Morrison, the water is taken from Bear Creek during the flood and non-irrigating seasons and conveyed through the Harriman ditch and a flume to Marston Lake for storage. It is then drawn out as needed for use, filtered through a mechanical filter, and flows by gravity through wooden pipes to the city distributing system.

4.—At Platte Cañon, where the South Platte River emerges from the mountains, a system of underground cribs is constructed to collect the underflow of water in the gravel and sand below the bed of the river and the adjacent valley. The water thus collected flows by gravity through a 30-in. wooden pipe into the Ashland Avenue Distributing Reservoir and into the city pipe system.

5.—About 2 miles above Platte Cañon, water is taken from the river into a 34-in. wooden pipe which leads to a mechanical filter, 2 miles south of Platte Cañon, and, after being filtered, flows by gravity to the Capitol Hill Reservoir and the city pipe system.

6.—In addition to the foregoing, there is now being constructed at Platte Cañon a slow sand-filter plant of about 30 000 000 galls. daily capacity, with provision for extending the filters, as the needs of the city require, to 100 000 000 galls. per day. The water for these filters is secured from the Platte River, under rights owned by the company, and from the Lake Cheesman Reservoir. The supply from the latter source is drawn from the reservoir and turned into the river below and flows in the river bed to Platte Cañon, a distance of about 30 miles, where it is taken from the river into the settling basins and then applied to the filter beds. After being filtered, the water flows by gravity in a 40-in. wooden pipe to the city distributing system.

To convey this water from the various sources of supply to the city requires the use of nearly 100 miles of pipe line, varying from 30 to 48 ins. in diameter. These conditions indicate, in part at least, the great difficulties and expense of securing in this region a water supply for a large city. The great problem is not the best way to distribute the water to the consumers, but how to obtain it.

Lake Cheesman Reservoir.

The first five sources of supply enumerated have furnished sufficient water up to the present time, but the management of the company, having great faith in the future rapid growth of the city,

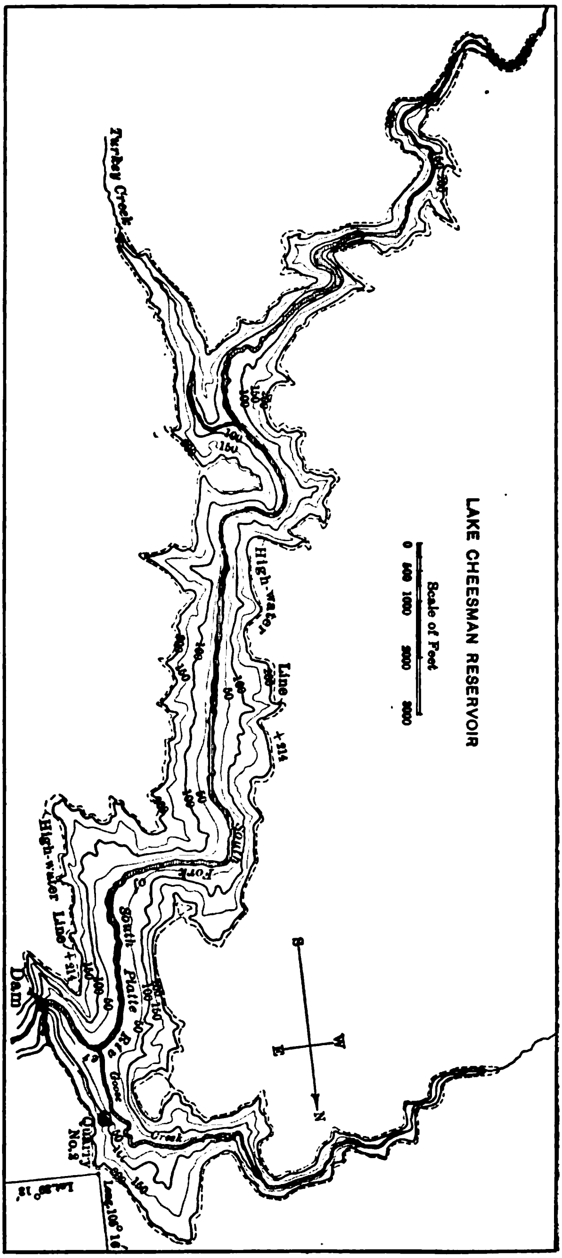

LAKE CHEESMAN RESERVOIR
Scale of Feet
0 500 1000 2000 3000
Turkey Creek
High-water Line +214
South Fork
South Platte River
Goose Creek
High-water Line +214
Dam
Quarry No. 2
N
S
E
W

FIG. 2

realized early the importance of securing the necessary water supply for this increased population. With this end in view, Mr. C. P. Allen, the Chief Engineer of the Company, inspected the South Platte River and its tributaries, and, finally, decided upon the location now known as Lake Cheesman as the one furnishing the best site for a dam and large reservoir with a water supply to fill it. The location of this site is in the South Platte Forest Reserve, in Jefferson and Douglas Counties, Colorado, and about 48 miles southwest from Denver (Fig. 1). A subsidiary company, The South Platte Canal and Reservoir Company, was formed for building the reservoir, and, for this purpose, secured the right of way from the Government. The first map was filed on October 8th, 1894, and approved by the Secretary of the Interior on August 19th, 1895. The Company owns about 8 500 acres of land, including and surrounding the reservoir, which ownership insures the protection of this water supply for all time.

The catchment basin, which has an area of about 1 796 sq. miles, is in the Rocky Mountains, on the South Fork of the South Platte River, and is more than 7 000 ft. above sea level. Its location is shown in Fig. 1, a water-shed map compiled from the maps of the United States Geological Survey. In order to make the outlines of the various water-sheds more easily followed by the eye, the map is drawn with the sources of the streams at the top, which brings the north at the bottom instead of at the top of the map, as is the usual custom. The surface of the ground is largely of rock and sand with very little vegetation; and the location in a forest reserve, where settlements which might pollute the waters are excluded, makes the basin an ideal water-shed for gathering potable water. The first habitation on the river above the reservoir is at Lake George, a distance of 25 miles, and the population within the entire area is less than 1.5 persons per square mile. All the streams tributary to the reservoir are precipitous and have rocky beds.

The entire area which will be flooded by the reservoir is of granite or granitic sand, there being no black soil or humus upon it. An inspection of the contour map (Fig. 2) shows that the sides of the reservoir are very steep, thus preventing shallow shore water in which vegetation might grow. The reservoir also has great depth and a comparatively small surface area exposed to evaporation, a considerable advantage in that climate. The source of supply is the melting

FIG. 1.—VIEW OF CAÑON LOOKING DOWN STREAM.

FIG. 2.—JUNCTION OF PLATTE RIVER AND GOOSE CREEK.

FIG. 3.—GENERAL VIEW OF DAM LOOKING DOWN STREAM.

on May 3d the flood overtopped the rock fill and washed it away completely, leaving only the masonry and steel facing. A view of the cañon taken a few days after this accident is shown in Fig. 2, Plate XV.

The Masonry Dam.

On June 1st, 1900, the writer was appointed Chief Engineer of the South Platte Canal and Reservoir Company and the Denver Union Water Company, with instructions to design and build a dam at this location, with the advice and assistance of L. E. Cooley, M. Am. Soc. C. E., who had been consulting engineer to the company during the previous year.

The important conditions which existed at that time were:

1.—The tunnels at Elevations 10, 60 and 110 had been driven. The balance valve at the entrance of the lower tunnel, and the twin valve in the middle of it, had been permanently set. The two 42-in. single valves for the upper tunnels had been purchased.

2.—The Portland cement masonry, together with the steel plates, had been built, up to Elevation 28, and remained in perfect condition after the flood.

3.—The Government had given five years in which to build the dam, and it was the desire of the management of the company to utilize as much as possible of the work which had already been done and to be as far advanced as possible with the new work at the expiration of the time limit, so as to be in a favorable position to ask for an extension of time in which to complete the work. In no case was the lake to be entirely unwatered.

The type of dam finally determined upon was, in plan and section, substantially that shown in Fig. 1, Plate XVII and Fig. 5, and was to be built to Elevation 210, with the spillway at Elevation 200. It was designed as a gravity section, but the configuration of the gorge was such that the natural form of dam to fit the site would be curved in plan. As the full cross-section of a gravity dam could be retained and the arch form used, with no additional masonry, it was decided to curve the up-stream face to a radius of 400 ft. It is built of granite masonry laid in Portland cement mortar. The contract for its construction was let in August, 1900, and the work was begun in September. After the dam had been built to an elevation of about 70,

the advisability of carrying it to a greater height than Elevation 210 was considered, with the view of increasing the storage capacity of the reservoir as much as possible, consistent with safety. Taking into consideration the contour of the cañon below Elevation 90, the arch form of dam, and the excellent stone available for its construc-

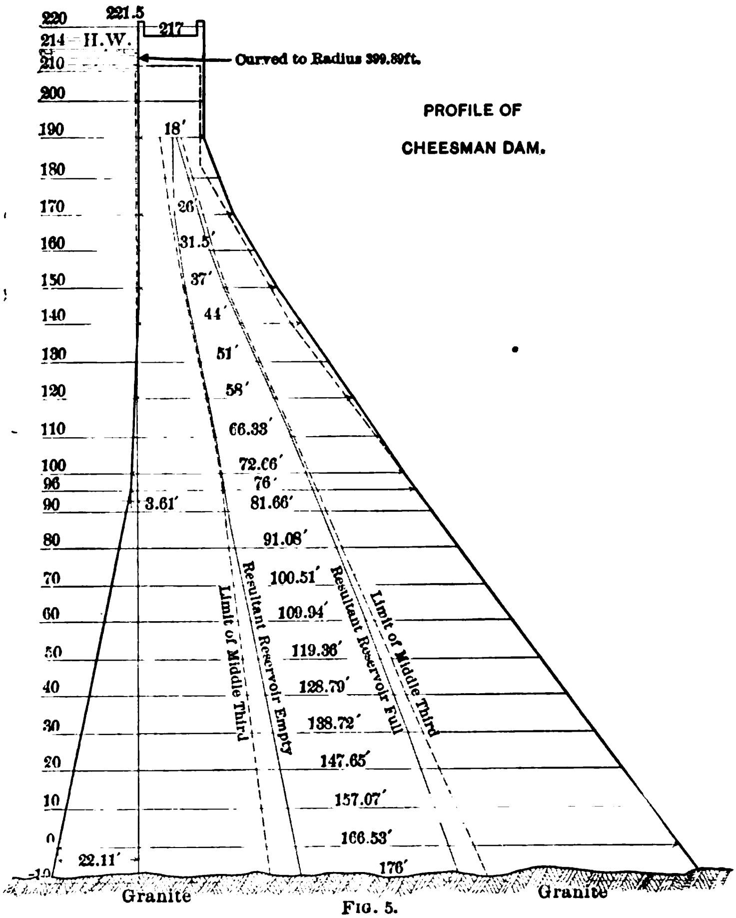
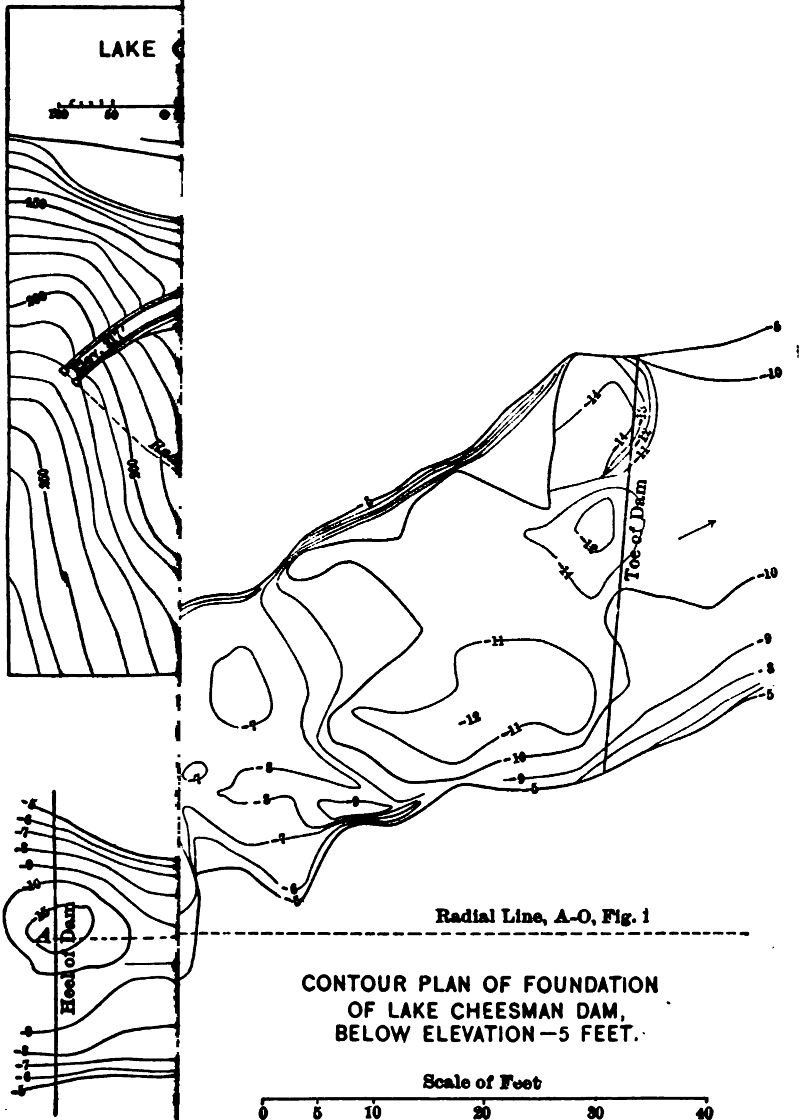


FIG. 5.

tion, it was thought that this could be done, and the problem worked out by the time Elevation 100 was reached with the construction. This elevation was therefore fixed as the point where the change of section should begin. Fig. 2, Plate XVIII, is a view of the cañon with the bottom of the trestle on the dam at about Elevation 100, and

PLATE XVII.
PAPERS, AM. SOC. C. E.
MARCH, 1904.
HARRISON AND WOODARD ON
LAKE CHEESMAN DAM AND RESERVOIR.



CONTOUR PLAN OF FOUNDATION
OF LAKE CHEESMAN DAM,
BELOW ELEVATION—5 FEET.

FIG. 2

the contours in Fig. 1, Plate XVII, give a fair outline of the dam at that elevation. A profile across the cañon is shown in Fig. 7. The question of determining the elevation to which the dam could be built with safety and the section to be adopted presented important and difficult problems. For the solution of them, and for the consideration of the sufficiency of the devices for regulating the outflow from the reservoir, an additional consulting engineer, Alfred Noble, Past-President, Am. Soc. C. E., was appointed.

After trying several sections, that shown in Fig. 5, with the spillway fixed at Elevation 212, was finally adopted. It was designed as a gravity section, but the arch form gives it additional strength. Silas H. Woodard, Assoc. M. Am. Soc. C. E., under the direction of the consulting engineers, made an analysis of the stresses in the dam which is of special interest on account of taking the arch form into consideration. His discussion of this subject is presented by him as a part of this paper.

In computing the weight of the dam, the specific gravity of the masonry is taken as 2.5, or 156.25 lbs. per cubic foot, but actual determinations of the specific gravity of the mortar and the stone (both being dry) in the proportions used in the dam, give a weight of 158 lbs. per cubic foot of masonry. The part of the dam built previous to 1902 was composed of 74% of stone and 26% of mortar.

In computing the stresses in the dam, no account is taken of the ice thrust, for two reasons: (1) Because it is not probable that the reservoir will ever be full during the winter season, and the heavier section of the dam at the water level is more than ample to resist this thrust; and (2) because the point of rock projecting into the reservoir in front of the dam will protect it in such a way as to make this thrust small. This point of rock is shown in Fig. 2 by the contours, and in Fig. 2, Plate XVIII, in the background over the top of the dam. The high-water line is about 10 ft. vertically below the timber-line shown in Fig. 2, Plate XVIII.

Foundation.—The foundation of the dam is the solid granite rock at the bottom of the cañon across which it is built. The widths of this cañon are as follows: At the bottom, about 30 ft.; at Elevation 30, about 40 feet; at Elevation 90, about 130 ft., on the down-stream face; and at Elevation 217, about 710 ft. (see Fig. 10). The elevation of the bed-rock along the axis of the stream is about — 10 ft., but one

pot-hole extended down to Elevation — 15 ft. In fact, the entire bottom was a series of pot-holes eroded in the solid granite and varying in depth from 1 ft. to 6 ft. Similar pot-holes also existed in the walls of the cañon, from the foundation up as high as Elevation 50; some of these, on the south side of the cañon, can be seen in Fig. 1, Plate XVI. Overlying the bed-rock were boulders and coarse gravel to a depth of about 8 ft. These were removed and the rock was washed clean before the masonry was laid. No unsound rock or crevices were found below Elevation 30, but, above this elevation, some broken and unsound rock was found, and all of it was removed before laying the masonry, thus giving a foundation on solid granite for the entire base of the dam. Generally, the excavation for the foundation consisted of removing large boulders and a few feet of disintegrated rock, but at the south end of the dam and above Elevation 130 there was encountered a large pocket of rock so badly broken up that it was not suitable for a good foundation. Smaller pockets of unsound rock were encountered on both the south and north sides of the cañon. The contour of the foundation of the dam as actually built upon is shown, from Elevation 0 to Elevation 130, by the dotted lines in Fig. 1, Plate XVII, and below Elevation — 5 in Fig. 2, Plate XVII.

Height of Dam and Depth of Water.—Referring to the section shown in Fig. 10, the average elevation of the base of the dam is — 10, and the driveway on top of the dam +217, thus making an average height of 227 ft. The extreme low point of the foundation is — 15 and the highest point of the top + 221, making a maximum height of 236 ft. The thickness of the base at Elevation — 10 is 176 ft., and at Elevation 190 it is 18 ft., which thickness is carried uniformly to the top of the structure. Since the material overlying the bed-rock on the up-stream side of the dam is open gravel and boulders, the water pressure against the dam may fairly be assumed to begin at Elevation — 10, and if 2 ft. of water is flowing over the spillway its surface will be at Elevation + 214, making the pressure against the dam that due to a depth of 224 ft. This exceeds very greatly the depth of water against any other dam yet built. There is practically no back pressure from water on the down-stream face of the dam.

Materials Used and Methods of Construction.

The cement used was Portland, and was furnished by the company, free of cost to the contractor, in a warehouse about 4 000 ft. north and

FIG. 1.—TOP OF DAM AT ELEVATION 181.

FIG. 2.—DOWN-STREAM FACE OF DAM. TOP OF MASONRY AT ELEVATION 181.

west of the dam. As the needs of the work demanded, it was issued to the contractor, who transported it to the work on scows or wagons, and was responsible for its protection and safekeeping.

It was purchased under the following specifications:

Chemical.—It shall contain neither free lime nor free magnesia, and not more than 2% of sulphate of lime, and the magnesia and oxide of iron shall not be excessive. It shall not be over-burned or under-burned.

Fineness.—Not more than 7% shall be retained on a No. 100 sieve, and not more than 25% on a No. 200 sieve.

Setting.—It shall not take its initial set in less than 45 minutes nor more than 3 hours, nor set hard in less than 3 hours nor more than 8 hours.

Soundness.—It shall show soundness by both the cold-water test and the hot-water test.

Strength.—The neat cement shall develop a tensile strength of 150 lbs. per square inch in one day, and 600 lbs. in 7 days, and show an increase of 15% in the next 21 days. When mixed with sand, as required for mortar, it shall develop a reasonable proportion of the strength of neat cement. Both neat cement and mortar shall show a reasonable increase in strength with age beyond 28 days.

The cement was tested in Denver and then shipped by railroad to Buffalo, a distance of 40 miles. From there it was hauled by teams over a mountain road to the dam, a distance of about 23 miles. In addition to the tests made at Denver, frequent tests for tensile strength of mortar, taken from the mortar boxes on the work, have been made, since 1902, by the resident engineer. Altogether, about 80 000 bbls. of cement will be required. Of this amount, 6 000 bbls., used in 1900, were of the Wolverine Brand. All the cement used since then has been the Iola Portland cement, made at Iola, Kansas.

The sand is furnished by the contractor and is secured from a gulch about 5 000 ft. north and west of the dam. It is run through a $\frac{3}{8}$-in. screen and washed, after which it is taken to the dam on scows or wagons. As actually used in the work, it contains, as determined by several analyses, less than one-tenth of 1% of volatile and organic matter, and has about 31% voids.

The mortar for laying the stone on the up-stream face and at the bottom and ends of the dam, adjoining the solid rock, is mixed in

proportions of 2 parts of sand to 1 part of cement by volume, and 95 lbs. of cement are taken as 1 cu. ft.; the mortar for the rest of the masonry is mixed in the proportion of 2½ to 1. The sand and cement are mixed dry, the proper quantity of water is added, and then the mixing is continued. A batch mixer, manufactured by the Iroquois Iron Works, of Buffalo, N. Y., is used for this purpose, and gives excellent results. It is located near the end of the dam, and the mortar, after being mixed, is dumped into cars which are moved along a track built on brackets on the up-stream face of the dam, as shown in Fig. 3, Plate XVI. From this track the mortar is hoisted to the work on the dam by the several derricks used for setting stone, thus avoiding any interference with the other derricks, and ensuring the delivery of the mortar at the point where it is to be used.

The stone used is a good gray granite. The stone for the up-stream face is obtained from Quarry No. 2 (Fig. 2) distant about 2 000 ft. north and west from the dam. The stones are rough-pointed, so as to be laid with horizontal beds and vertical joints, and the outside edges are made to conform to the curvature of the dam. No attempt is made to dress the exposed faces of the stones. The specifications required them to be laid with ⅜-in. joints, but this requirement was modified, with the approval of the consulting engineers, so as to permit 1-in. joints, in the belief that the thicker bed of mortar would be more nearly water-tight. The specifications also allowed these stones to be laid in broken courses, but the contractors preferred to have them of a uniform thickness, and all the face stones are uniformly 2 ft. thick. All joints are raked out to a depth of 1½ ins. and pointed with 2 to 1 mortar. The specifications required that one-fourth of the face area should be headers, from 4 to 6 ft. long, not less than 2 ft. wide, and evenly distributed through the wall. The stretchers were to be not less than 3 ft. and not more than 7 ft. long, with a width not less than one and one-half times the thickness. The stones for the down-stream face are not dressed, but are large and well shaped, and of a thickness approximating 2 ft. They are selected and laid in steps, so as to give a good appearance for rough work. The rubble for the interior of the dam is of good-sized stones, well shaped, and laid so as to break joints and bond in all directions. In laying the stones a full bed of soft mortar is required, and, in filling in between the large stones, it is required that the space shall first be

FIG. 1 —ENTRANCE TO LOWEST TUNNEL.

FIG. 2.—TWIN VALVES IN TUNNEL.

filled with mortar and the smaller stones then worked down into it. This is considered a very important feature in building water-tight masonry, and, so far, it has proved effective in this case. During the past summer the water stood in the reservoir at about Elevation 97, and there was no evidence of a leak or even sweating on the lower face of the dam. The stone for the down-stream face and the interior of the dam is secured from Quarry No. 1 (Fig. 1, Plate XVII), situated just below the dam. It is transported from the quarry to the toe of the dam on small cars, from which it is hoisted to cars running on a trestle built along the face of the dam. See Fig. 2, Plate XVIII. The building derricks take the stone from these cars as needed for use in the work. This arrangement for distributing the stone avoids any interference of one derrick with another.

The stones for the interior of the dam are set so as to bond vertically as well as horizontally, and special care is taken not to level up the work at any point throughout the thickness of the wall. This, in addition to giving the proper bond, makes it very difficult for water to enter into or seep through the dam. The photograph, Fig. 1, Plate XVIII, taken when the top of the masonry was at Elevation 131, is a fair illustration of how the stones were disposed, and also shows the shape of the stones used in the work. In the quarry, large masses of stone are loosened with powder and are then reduced by plug-and-feather to the proper size for building into the dam.

Devices for Regulating the Outflow.

As a part of the plan for building the rock-fill dam, already mentioned, it was proposed to draw the water from the reservoir by tunnels driven through the granite mountain, as shown by the solid lines in the plan and the "Section on Tunnel Line," Fig. 1, Plate XVII.

Before the writer's connection with the work, these tunnels had been driven, and a balance valve, protected by a grating, had been set permanently at the intake of the lower tunnel, as shown in Fig. 1, Plate XIX. In addition to this, a 42-in. twin valve had been set at about the middle of this tunnel, a view of which is shown in Fig. 2, Plate XIX. The balance valve was designed to be operated by a hydraulic cylinder, the water supply for which was to be carried in

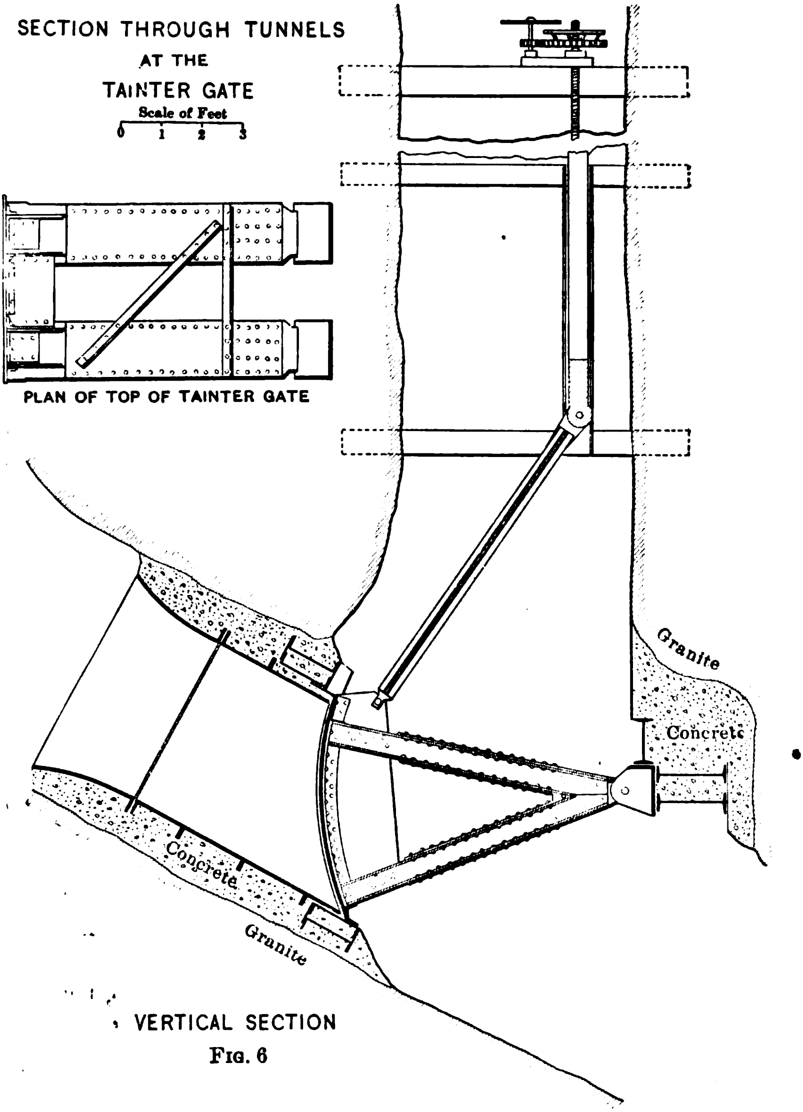
pipes along the bottom of the tunnel from its portal to the valve, and a waste pipe was provided in the same manner. The twin valves were to be operated by hydraulic cylinders supplied with water in a similar manner. The valves in the 60-ft and 110-ft. tunnels had been provided, but were not set.

The fact that no provision had been made to give access to the working parts of these valves when water was being drawn out through the tunnels seemed to be a serious objection, and was met by driving a separate "Manway tunnel," as shown by the dotted lines in Fig. 1, Plate XVII, thus at all times giving free access to the working parts of the valves and also providing a safe means of piping the water for operating them. It was also thought advisable to provide means for creating a back pressure on the valves in the 60-ft. and 110-ft. tunnels, so as to make them easily operated when the reservoir was full. For this purpose, a "Tainter Gate," to be operated by hand, was designed and placed just below the junction of the two tunnels, as shown in Fig. 1, Plate XVII, and Fig. 6. It is probable that this gate may prove to be the best one to operate, under ordinary conditions, for drawing water out of the reservoir.

Spillway.

After the reservoir is filled, the flood water will discharge from it into the river below the dam, over a spillway about 300 ft. long, at Elevation 212. The south end of the spillway is about 200 ft. north of the north end of the dam, as shown in Fig. 1, Plate XVII, and Fig. 3, Plate XVI, and is in a natural saddle in the rock ridge. The surface of the rock varies from about Elevation 195 at the south end to Elevation 225 at the north end. Where the rock is above Elevation 212, it is to be excavated to that level and the lower portion is to be built up with rubble masonry, similar to that in the main dam, to Elevation 212 and a top width of 14 ft.

The maximum flood recorded in the river occurred in June, [illegible]0, and was 1 945 cu. ft. per second. Several times this volume of water would discharge over the spillway before the level of the lake would reach the top of the dam. In addition to this the storage capacity of the reservoir will act as an equalizer, and more than 1 000 cu. ft. per second can be drawn off through the tunnels.



VERTICAL SECTION

FIG. 6

QUANTITIES.

The principal quantities of work involved in the construction of the reservoir, dam and appurtenances are as follows:

1.—Excavating 26 000 cu. yds. of earth and rock for foundations.

2.—Driving about 1 300 ft. of water and manway tunnels, and setting five valves in these tunnels, and gratings at the intakes.

3.—Building 103 000 cu. yds. of masonry.

4.—Clearing about 1 000 acres of timber and brush from the site of the reservoir.

The striking features of the location for this reservoir and dam are:

1.—A rocky, mountainous water-shed, producing but little vegetation and containing a small population, which makes it practically free from pollution.

2.—A reservoir site, composed of granite rock or granitic sand, of such contour as to give great depth and capacity with a small surface area.

3.—A site for the dam which affords good, solid foundations and a narrow cañon for the lower part of the structure, thus making the quantity of masonry required comparatively small. To this is added a good rock foundation for a spillway at a convenient location.

The writer's connection with this work ended on May 24th, 1902, at which time the masonry of the dam was completed to about Elevation 134, and the contracts then let provided for building it to Elevation 210. The reservoir site had been cleared, and the tunnels were nearly completed. No contracts had been let for that part of the masonry in the dam above Elevation 210, nor for the excavation and masonry between the north end of the dam and the north end of the spillway. The general plan of this part of the work was as shown in Fig. 1, Plate XVII, but the details, as actually built, have been designed by Alexander E. Kastl, M. Am. Soc. C. E., who has been Chief Engineer of the company since May 24th, 1902.

On January 1st, 1904, the main dam was completed for nearly its entire length to Elevation 217, and it is expected that the entire work will be completed before July 1st, 1904. The masonry and excavation have been done under contract by The Geddis and Seerie Stone Company, and all other work has been done by the company by day's labor.

FIG. 1.—VIEW OF TOP OF DAM LOOKING NORTH. ELEVATION 210.

FIG. 2.—VIEW OF TOP OF DAM LOOKING NORTH. ELEVATION 217.

In addition to the Chief and Consulting Engineers already mentioned, the following have been immediately connected with the work:

James E. Maloney, Resident Engineer to April 1st, 1902; Frank C. Horn, M. Am. Soc. C. E., Resident Engineer since April 1st, 1902; John A. Runner, Assistant Engineer; M. A. McGraw and C. C. Murphy, Inspectors.

Part II.

ANALYSIS OF STRESSES IN LAKE CHEESMAN DAM.

By Silas H. Woodard, Assoc. M. Am. Soc. C. E.

Most of the dams which have been built during the last fifty years have been straight in plan, depending upon their weight for stability.

In a few cases, where the dams have closed very narrow valleys, they have been curved up stream, and designed as arches to transmit all the thrust of the water to the sides of the valley. There is a third type, still fewer in number, located in moderately narrow valleys, which have been made the full, or nearly full, cross-section which would be required for a gravity dam, and, besides, have been curved in plan.

What is practically a standard method of analysis of stresses in a gravity dam, based upon the usual assumption of uniformly varying stress, has been developed. This method is simple, and may be found, with variations, in detail in the textbooks and works upon masonry, and has been used in the design of practically all modern dams.

The analysis of stresses of the purely arch dams has been made after still more common methods in use for all masonry arches. Many objections to this method of treatment have been raised. The objectors have argued that the fact that the horizontal arch is held rigidly at the base of the dam upsets the whole assumption that the dam acts simply as an arch. If the arched form is maintained and the thickness is increased, so that the structure has considerable strength as a gravity section, this argument has even greater force.

The Lake Cheesman Dam belongs to this last class, of combination gravity and arch dams, and the analysis of stresses was made in three ways.

In the first its cross-section was examined as a gravity section by the methods usually applied to gravity dams.

In the second the stresses were computed when the dam was considered as a simple horizontal arch. This was done only incidentally and with no idea that the assumptions at all approximated the actual conditions, but it shows what the strength of the arch would be if it could be developed. The dam could not fail without developing this strength.

The third analysis takes account of the combined action of the gravity section and the horizontal arch.

There is nothing novel in the first two treatments, and the only excuse for this paper is found in the third. The method here used is not itself novel, but it has not been usually applied to masonry dams.

The analysis of the stresses in every engineering structure, with a very few exceptions, is based upon the assumption that all particles lying in a plane before stressing will lie in a plane after stressing, and that stress is proportional to strain, or, as it is commonly expressed, the stress is uniformly varying along any plane.

This law of distribution of stress has been tested as to its correctness, when applied to the common cases of steel, timber and small masonry construction, by the most refined laboratory experiments, and also by the success of countless structures for which it has formed the basis of design. Yet it must have its limit of practical application, and great care should be exercised in extending it to new fields.

It is an open question whether or not the application of the law to a masonry dam, 150 ft. thick at its base, is an unwarranted assumption. It will probably remain so until some one expends the time and money to make the delicate measurements necessary to solve the problem.

While the applicability of the law to masonry dams is not as well demonstrated as to an I-beam, for example, there are very good theoretical reasons for believing that, even if the law is not rigidly correct when applied to masonry dams, its error is on the safe side. Besides this, the law has been applied to the design of masonry dams for half a century, and, as far as known, every successful dam satisfies the requirements of stability which are founded upon the law, and all failures may be explained either by a disregard of those requirements or by other obvious reasons.

Granting the correctness of the above law, the stresses for any loading of the structure may be computed by any one of a great variety of methods. By comparing these stresses with known safe limits, the safety of the structure may be judged.

In the following computation of the stresses in the dam as a gravity section, the prism of masonry included between two parallel, transverse, vertical planes, 1 ft. apart, is considered to resist the water pressure against its up-stream face.

This prism of masonry is considered to be divided into layers by imaginary horizontal joints or planes 10 ft. apart, as indicated in Fig. 5. The condition of stress is then computed at each one of these joints.

Let b = the breadth of the horizontal joint;

W = the weight of the masonry above the joint, in terms of the weight of a cubic foot of masonry = the sectional area above the joint (weight of 1 cu. ft. of masonry = 156.25 lbs.);

P = the horizontal thrust of the water pressure acting above the joint, in terms of the weight of a cubic foot of masonry $= \frac{d^2}{2} \times \frac{62.5}{156.25} = \frac{d^2}{5}$;

d = the depth of the joint below high water = 214 = the elevation of the joint;

S_1 = the batter of the up-stream face of the dam in the 10 ft. above the joint;

S_2 = the batter of the down-stream face of the dam in the 10 ft. above the joint;

M = the moment of all the masonry above the joint about its up-stream edge;

n = the distance from the up-stream side of the dam to the resultant for reservoir empty $= \frac{M}{W}$;

a = the angle which the resultant for reservoir full makes with the vertical;

tan. $a = \frac{P}{W}$ = the coefficient of friction required to prevent sliding;

v = the distance between the positions of the resultants for reservoir full and reservoir empty $= \frac{P}{W}\frac{d}{3} = \frac{d^3}{15\,W}$;

$n - \frac{b}{3}$ = the distance which the resultant for reservoir empty falls inside the middle third;

$\frac{2b}{3} - (n + v) =$ the distance which the resultant for reservoir full falls inside the middle third;

$f_1 =$ the vertical intensity of pressure, in pounds per square foot, at the up-stream edge of the joint, for reservoir empty $= \frac{312.5\ W}{b^2}(2\ b - 3\ n)$;

$f_2 =$ the vertical intensity of pressure, in pounds per square foot, at the down-stream edge of the joint, for reservoir empty $= \frac{312.5\ W\ (3\ n - b)}{b^2}$;

$f'_1 =$ the vertical intensity of pressure, in pounds per square foot, at the up-stream edge of the joint, for reservoir full $= \frac{312.5\ W\ (2\ b - 3\ (n + v))}{b^2}$;

$f'_2 =$ the vertical intensity of pressure, in pounds per square foot, at the down-stream edge of the joint, for reservoir full $= \frac{312.5\ W\ (3\ (n + v) - b)}{b^2}$.

The results of the computation at each horizontal joint are given in Table No. 2.

It is usually required that friction alone should be sufficient to prevent sliding along any horizontal plane. This requires that the resultant at any horizontal joint shall make an angle with the vertical the tangent of which is less than the coefficient of friction.

In the Lake Cheesman Dam there is nothing like a horizontal joint, for great care has been taken to make vertical bonds, and the masonry can be relied upon to develop great strength in shear. However, the required coefficients of friction to prevent sliding have been worked out in the table.

Two columns are also given showing the amount that the resultants, for reservoir full and reservoir empty, fall inside the middle third of each horizontal joint.

The positions of the resultants are plotted in Fig. 5.

This treatment of the curved dam must be considered, at best, as an approximation, and has force only if it be assumed that of two dams of the same cross-section, one of which is curved, with rigid abutments, and the other straight, the curved one will be at least as strong as the other.

TABLE No. 2.—COMPUTATION OF STRESSES IN DAM AT LAKE CHEESMAN.

Elevation of joint.	Breadth of joint. b	Total masonry above joint. W	Batter of up-stream face in 10 ft. above joint. S_1	Batter of down-stream face in 10 ft. above joint. S_2	Moment of masonry about up-stream edge. M	Distance from up-stream edge to resultant, reservoir empty. N	Distance between results, reservoir full and reservoir empty. V	Tan. a	$n - \frac{b}{3}$	$\frac{2}{3}b - (n+v)$	Reservoir Empty. Stress on up-stream edge.	Reservoir Empty. Stress on down-stream edge.	Reservoir Full. Stress on up-stream edge.	Reservoir Full. Stress on down-stream edge.
190......	18	504	0	......	4 536	9	1.96	0.25	3	1.04	4 330	4 330	1 520	7 230
180......	22	704	0	4	6 543	9.29	3.72	0.33	1.96	1.66	7 330	2 670	2 260	7 740
170......	26	944	0	4	9 490	10	6.01	0.41	1.33	1.82	9 600	1 550	1 540	9 600
160......	31.5	1 232	0.14	5.36	13 727	11.14	8.52	0.47	0.64	1.33	11 480	740	1 560	10 670
150......	37	1 574	0.14	5.36	19 801	12.58	11.10	0.52	0.25	0.98	13 030	270	1 064	12 230
140......	44	1 979	0.6	6.4	29 085	14.69	13.64	0.55	0.08	1.00	14 030	20	1 150	12 900
130......	51	2 454	0.6	6.4	41 724	17.00	16.10	0.58	0.00	0.90	15 030	0	800	14 240
120......	58	2 999	0.6	6.4	58 228	19.41	18.46	0.59	0.08	0.89	16 100	60	670	15 500
110......	65.33	3 616	0.6	6.73	79 245	21.91	20.75	0.60	0.13	0.90	17 200	100	710	16 600
100......	72.66	4 306	0.6	6.73	105 836	24.45	22.96	0.60	0.28	1.08	18 350	180	790	17 730
90......	81.66	5 072	1.486	7.514	142 598	28.11	25.06	0.61	0.89	1.27	18 730	630	910	18 510
80......	91.08	5 936	1.927	7.5	190 522	32.09	27.02	0.61	1.73	1.61	19 200	1 100	1 060	19 280
70......	100.51	6 894	1.927	7.5	248 790	36.09	28.87	0.60	2.59	2.10	19 780	1 650	1 810	20 130
60......	109.94	7 946	1.927	7.5	318 470	40.08	30.64	0.60	3.43	2.58	20 490	2 120	1 590	21 020
50......	119.36	9 092	1.927	7.5	400 627	44.06	32.34	0.59	4.27	3.18	21 240	2 550	1 900	21 690
40......	128.79	10 330	1.927	7.5	496 339	48.05	33.99	0.59	5.12	3.82	22 030	2 990	2 230	22 830
30......	138.22	11 668	1.927	7.5	606 679	52.00	35.68	0.58	5.93	4.46	23 010	3 400	2 560	23 850
20......	147.65	13 098	1.927	7.5	732 718	55.94	37.16	0.57	6.72	5.33	23 940	3 790	3 000	24 750
10......	157.07	14 621	1.927	7.5	875 505	59.86	38.71	0.57	7.50	6.14	24 910	4 030	3 410	25 660
0......	166.58	16 239	1.927	7.5	1 036 184	63.80	40.23	0.56	8.30	6.97	25 930	4 560	3 830	26 660
−10......	175.98	17 951	1.927	7.5	1 215 679	67.96	41.74	0.56	9.32	7.58	26 830	5 070	4 130	27 770

It was assumed that a prism of masonry cut by parallel planes resisted the water pressure upon 1 ft. length of dam. In reality, a wedge of masonry cut by radial planes must resist this water pressure. At the toe this wedge would be only six-tenths of its thickness at the upstream face.

There is little doubt that the curved form, of the same cross-section, is as strong as the straight, and the whole question might be left here with confidence in the stability of the dam. But this is only another way of saying that the arch must carry its part of the load, and relying on it to do so without any measure of how much this part is.

It was thought very desirable to gain a better idea of what part of the load is resisted by the arch and what part by the gravity section. To accomplish this, the following method of analysis was used:

It is evident that the load will be divided between the arch and the gravity dam in proportion to their relative rigidities, and it is upon this that the analysis is based.

The gravity section might have been treated as a vertical cantilever beam projecting upward from the foundation.

If the stresses in this beam had been computed by the usual method of treating beams, and these stresses corrected for the weight of masonry lying above the section considered. the same results would have been obtained as those given in Table No. 2. In the following analysis this method was used.

Any structure which resists force must suffer deformation, and, if the material is not stressed beyond its elastic limit, the amount of deformation is proportional to the force which produces it. In other words, the amount of deformation is a measure of the forces which cause it.

The structure may be built so that one simple system is deformed under load, as in the case of a simple girder or a simple arch: in that case it is evident that the one system which is deformed is sustaining the whole load. If, however, two or more systems are deformed, which would be the case if, for example, the middle of a beam rested upon an arch or a strut, then it follows that the load is divided between the two systems in proportion to their rigidity. This is the case of the curved masonry dam. The thrust of the water on the upstream face causes the dam to deflect down stream. This means that the horizontal arch is distorted and therefore resists a certain amount of thrust which it transmits to the sides of the valley, and the dam

considered as a gravity section, or, as pointed out before, as a cantilever beam projecting upward from the foundation, is also deformed, and therefore resists a certain amount of the load, which it conducts to the base of the dam. The problem is to determine how much of the load goes each way, and then to test each system for its ability to carry its load with safety.

The method to be pursued is to divide the dam above Elevation 55, which, for reasons to be given later, will be considered to be its base, into five arch rings by horizontal planes at Elevations 100, 130, 160 and 190. An expression will be developed which will give the deflection of each of these arches, in terms of its properties and the load which it resists.

Another set of expressions will be developed which will give the deflections of the points on the dam at the elevations of the middle of the arch rings, if the dam is considered as a vertical beam, in terms of the properties of the vertical beam and the loads which it resists.

It is useless to attempt an exact solution of the problem, as the outlines of the structure are not sufficiently regular, and to enter into too great refinements would complicate the solution, which, at best, is somewhat involved. However, an exact solution is not necessary, nor especially desirable. If whatever approximations are made are upon the safe side, and results can be gotten which are known to be within limits which are not too wide, the solution is nearly as satisfactory and quite as valuable, as a test of the safety of the structure, as though it were exact.

In the Lake Cheesman Dam, if it be considered that the dam, acting as an arch, carries all the load, the stresses would not be excessive. This, in itself, is a very good guaranty of the stability of the dam, for if it should fail utterly as a gravity section it could never be carried away until it had failed as an arch, and it seems safe against such a failure. It follows, then, that if either feature of the dam is in danger it must be the gravity section, and, therefore, the safe side, in an assumption for the calculation, is the one which throws the greater load upon the vertical cantilever or gravity section.

There are two assumptions that it is necessary to make, to simplify the work.

First, it is assumed that the line of thrust in the arch coincides with its center line throughout its length. In other words, the effect of the fixed abutments is neglected. This is on the safe side, for the

effect of the fixed abutments is to stiffen the arch and make it take more of the load, leaving less for the gravity section.

Second, it is assumed that the bottom of the dam follows the dotted lines a b c in Fig. 7. This, again, is on the safe side, for, if the

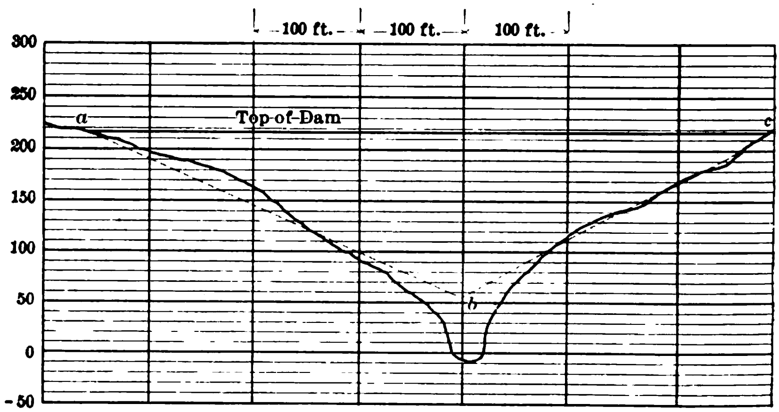


FIG. 7

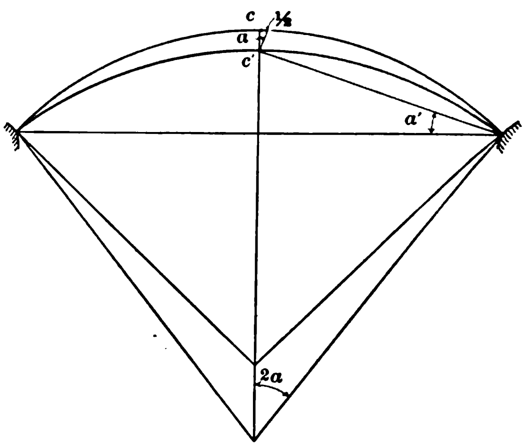


FIG. 8

bottom of the dam at its middle were at b, Fig. 7, the vertical cantilever would be shorter, and therefore stiffer, than it actually is, and, therefore, it would take more load than it actually does. Or, looked at in another way, the assumption places the bed-rock at b, and implies

that it is perfectly rigid. As a matter of fact, there is a mass of 65 ft. of masonry below b which is stressed at its down-stream edge to, say, 30 000 lbs. per square foot, and must compress, allowing the dam to deflect at the middle still more than has been assumed, and throwing more of the load upon the arches and less upon the gravity section than has been assumed. Let Fig. 10 represent a section of the dam at its middle, or at b, Fig. 7, showing the section of the horizontal arches. Let the arches be numbered from the top down, and let all subscripts refer to this numbering. Consider a vertical beam fixed at b, Fig. 7, and consisting of the masonry enclosed between two vertical radial planes 1.002 ft. apart at the up-stream top edge of the dam. Consider this beam to rest against the horizontal arches at Elevations 205, 175, 145, 115 and 85, and suppose the water pressure to be concentrated at these points. These pressures, in terms of the weight of a cubic foot of masonry, are:

$$P_1 = 115$$
$$P_2 = 468$$
$$P_3 = 831$$
$$P_4 = 1\,197$$
$$P_5 = 1\,573$$

Let the loads upon the vertical beams at Elevations 205, 175, 145, 115 and 85 be X_1, X_2, X_3, X_4, and X_5. It will be assumed, for the moment, that the arches have a uniform loading throughout their length. This loading must then be $P - X$. Later, this assumption will be shown to be warranted.

If, as has been assumed, the arch has hinged ends, its deflection will be as indicated in Fig. 8, that is, the deflection is uniformly increasing from the ends toward the middle.

Let A = the sectional area of an arch ring;
R = the radius of its up-stream edge;
E = the modulus of elasticity of the masonry;
a = one-fourth the angle which the arch subtends;
T = the thrust in the arch ring;
L = the length of the center line of the arch ring;
l = the shortening of the arch ring under compression;
c = the initial position of the crown of the arch (see Fig. 8);
c' = the position of the crown after deflection;

$D =$ the deflection of the crown of the arch;

$$D = \frac{l}{2} \cot. \ a;$$

but $$l = \frac{T L}{A E} = \frac{(P - X) R L}{A E}.$$

Then $$D = \frac{(P - X) \ R \ L \cot. \ a}{2 \ A \ E} \qquad \text{(I)}$$

The following are the values of R, L, A and cot. a, for the several arches:

$R_1 = 400$	$L_1 = 580$	$A_1 = 504$	cot. $a_1 = 2.5$
$R_2 = 400$	$L_2 = 400$	$A_2 = 728$	cot. $a_2 = 3 \ 7$
$R_3 = 400$	$L_3 = 270$	$A_3 = 1\ 222$	cot. $a_3 = 4 \ 7$
$R_4 = 402.4$	$L_4 = 200$	$A_4 = 1\ 851$	cot. $a_4 = 7.1$
$R_5 = 405.7$	$L_5 = 130$	$A_5 = 2\ 589$	cot. $a_5 = 11.4$

Before going farther, the stress in the arches, if the structure had no resistance whatever as a gravity dam, will be investigated. We now have all the elements for substituting in the approximate formula,

$$F = \frac{P \ R}{A},$$

for stress in an arch.

For 1st arch, $F = \frac{115 \times 400 \times 156.25}{504} = 14\ 000$ lbs. per square foot.

For 2d arch, $F = \frac{468 \times 400 \times 156.25}{728} = 40\ 000$ lbs. per square foot.

For 3d arch, $F = \frac{831 \times 400 \times 156.25}{1\ 222} = 42\ 500$ lbs. per square foot.

For 4th arch, $F = \frac{1\ 197 \times 402.4 \times 156.25}{1\ 851} = 41\ 200$ lbs. per square foot.

For 5th arch, $F = \frac{1\ 573 \times 405.7 \times 156.25}{2\ 589} = 38\ 500$ lbs. per square foot.

By this it is seen that the arches would not be over-stressed if the dam had no resistance as a gravity section.

By substituting the values of R, L, H and cot. a, in Equation I, the following set of equations results:

$$E \ D_1 = 575.4 \ (P_1 - X_1) = 66\ 170 - 575.4 \ X_1$$
$$E \ D_2 = 406.6 \ (P_2 - X_2) = 190\ 300 - 406.6 \ X_2$$
$$E \ D_3 = 207.7 \ (P_3 - X_3) = 172\ 600 - 207.7 \ X_3$$
$$E \ D_4 = 154.5 \ (P_4 - X_4) = 184\ 950 - 154.5 \ X_4$$
$$E \ D_5 = 116.1 \ (P_5 - X_5) = 182\ 600 - 116.1 \ X_5$$

These are E times the deflections of the crown of the several arches, in terms of the loads on the vertical beam.

These same deflections will now be expressed in terms of the properties of the vertical beam and its load.

The deflection of the dam, considered as a vertical beam, is expressed by the formula:

$$D_n = \int_0^H \frac{M\,d\,M}{E\,I\,d\,X_n}\,d\,y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(II)}$$

in which M = the bending moment at any point;

I = the moment of inertia of the beam;

E = the modulus of elasticity;

H = the height of the dam = the total length of the beam;

D_n = the deflection of any loaded point, from the position of the beam without loads. D must be measured in the direction of the action of the load X_n.

For the reason that this formula does not appear very generally in textbooks, it will be demonstrated here.

Let any beam be acted upon by loads $X_1, X_2 \ldots\ldots\ldots X_n$ at points $D_1, D_2 \ldots\ldots\ldots D_n$.

Let the movement of these points under load be $D_1, D_2 \ldots\ldots\ldots D_n$. In passing from one condition of loading to another, work is done. The total work of all the external forces acting upon the beam is $-W = \sum \frac{P\,D}{2}$.

By the doctrine of the conservation of energy, this must be equalled by the internal work done in distorting the beam. This internal work is done in lengthening and compressing the material, and is stored as potential energy in the material, to be given back if the forces are removed and the beam springs back to its initial position.

In Fig. 9:

Let $c\,c$ be an infinitesimal portion of length, $d\,y$, of the neutral axis of the beam under stress;

$n\,n'$ and $m\,m'$ be normal sections;

i be the angle, $n'\,c\,r'$;

z be the distance from the neutral axis to any point, q, on the section, $n\,n'$;

f be the stress at the point, q;

$Z_1 = c\,n$;

$Z_2 = c\,n'$.

Before the beam was stressed, $n\ n'$ was parallel to $m\ m'$, or in a position, $r\ r'$.

The average force acting upon a unit area at q is $\frac{f}{2}$, and the distance through which it acts is $z\ i$.

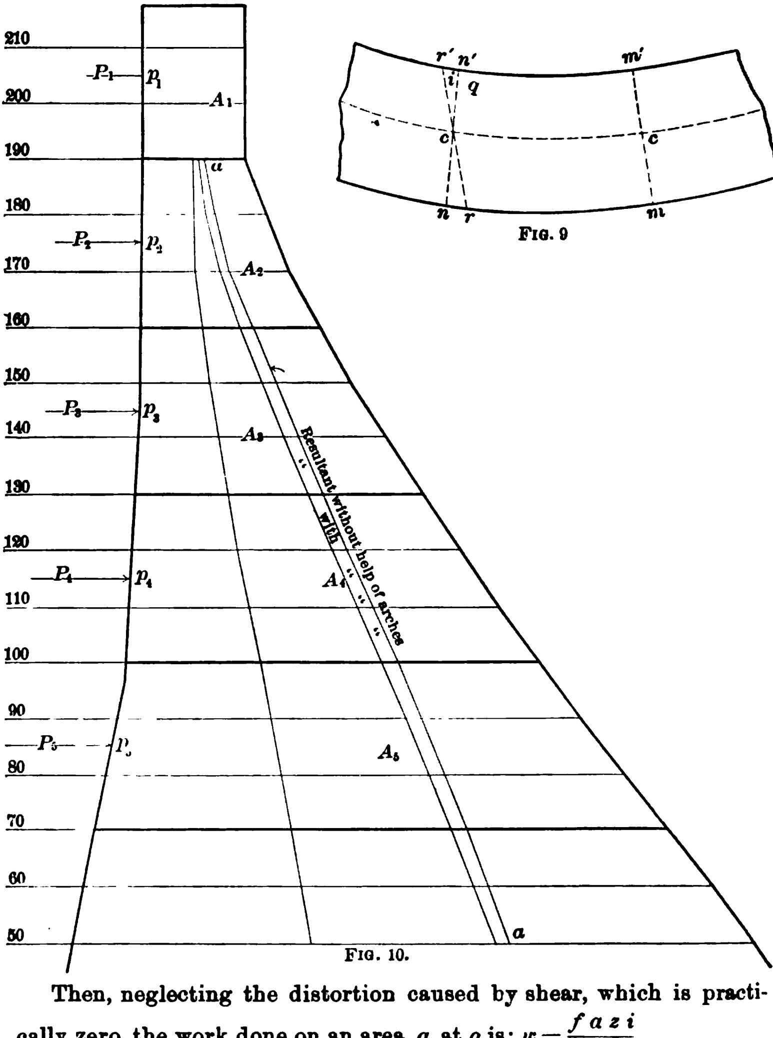


FIG. 9

FIG. 10.

Then, neglecting the distortion caused by shear, which is practically zero, the work done on an area, a, at q is: $w = \frac{f\ a\ z\ i}{2}$.

The work upon the whole prism, $n\ n'\ m'\ m$, is:

$$W = \sum_{Z_1}^{Z_2} \frac{f\ a\ z\ i}{2}.$$

The total internal work in the whole beam is:

$$W = \sum_{o}^{H} \sum_{-Z_1}^{Z_2} \frac{f\,a\,z\,i}{2}.$$

The total external work done upon the beam is:

$$W = \frac{P_1 D_1 + P_2 D_2 \text{ - - - - } P_n D_n}{2}.$$

Equating external with internal work, and clearing of fractions, we have:

$$P_1 D_1 + P_2 D_2 \text{ - - - } P_n D_n = \sum_{o}^{H} \sum_{-Z_1}^{Z_2} f\,a\,z\,i.$$

Differentiating this equation with respect to P_n, we have:

$$D_n = \sum_{o}^{H} \sum_{-Z_1}^{Z_2} \frac{d f}{d P_n} a\,z\,i.$$

But, $$f = \frac{M z}{I}.$$

Then, $$\frac{d f}{d P_n} = \frac{d M}{d P_n} \frac{z}{I};$$

and $$z\,i = \frac{f\,d y}{E} = \frac{M z\,d y}{E I}.$$

Substituting the values of $\frac{d f}{d P_n}$ and $z\,i$, we have:

$$D_n = \int_{o}^{H} \sum_{-Z_1}^{Z_2} \frac{d M}{d P_n} \frac{z}{I} \frac{a M z\,d y}{E I} =$$

$$\int_{o}^{H} \frac{d M}{d P_n} \frac{M}{E I^2} \sum_{-Z_1}^{Z_2} a\,z^2\,d y;$$

but $$\sum_{-Z_1}^{Z_2} a\,z^2 = I.$$

We therefore have

$$D_n = \int_{o}^{H} \frac{d M}{d P_n} \frac{M}{E I} d y \text{.............Q. E. D.}$$

Let M_1 be the bending moment at any point between p_1 and p_2, Fig. 10, and M_2 between p_2 and p_3, and so on for M_3, M_4 and M_5.

Let I_1 be the average moment of inertia between p_1 and p_2, I_2 the same between p_2 and p_3, etc.

Let y be the distance measured downward from any load point toward the next.

Then $M_1 = y X_1$, and $\frac{d M_1}{d X_1} = y$

$$\int_o^a \frac{d M_1 M_1}{E I_1 d X_1} d y = \frac{a^3}{6 E I_1} (2 X_1)$$

$$M_2 = (y + a) X_1 + y X_2$$

$$\frac{d M_2}{d X_1} = y + a, \qquad \frac{d M_2}{d X_2} = y$$

$$\frac{d M_2 M_2}{d X_1} = (y^2 + 2 a y + a^2) X_1 + (y^2 + a y) X_2$$

$$\int_o^a \frac{d M_2 M_2}{E I_2 d X_1} d y = \frac{1}{E I_2}$$

$$\left[\left(\frac{a^3}{3} + a^3 + a^3\right) X_1 + \left(\frac{a^3}{3} + \frac{a^3}{2}\right) X_2\right] =$$

$$\frac{a^3}{6 E I_2} (14 X_1 + 5 X_2)$$

$$\frac{d M_2 M_2}{d X_2} = (y^2 + a y) X_1 + y^2 X_2$$

$$\int_o^a \frac{d M_2 M_2 d y}{E I_2 d X_2} = \left[\left(\frac{a^3}{3} + \frac{a^3}{2}\right) X_1 + \frac{a^3}{3} X_2\right] \frac{1}{E I_2} =$$

$$\frac{a^3}{6 E I_2} (5 X_1 + 2 X_2)$$

$$M_3 = (2 a + y) X_1 + (a + y) X_2 + y X_3$$

$$\frac{d M_3}{d X_1} = (2 a + y), \quad \frac{d M_3}{d X_2} = a + y, \quad \frac{d M_3}{d X_3} = y$$

$$\frac{d M_3 M_3}{d X_1} = (4 a^2 + 4 a y + y^2) X_1 + (2 a^2 + 3 a y + y^2) X_2 +$$

$$(2 a y + y^2) X_3$$

$$\int_o^a \frac{d M_3 M_3 d y}{d X_1} = \frac{1}{E I_3}$$

$$\left[\left(4 a^3 + 2 a^3 + \frac{a^3}{3}\right) X_1 + \left(2 a^3 + \frac{3 a^3}{2} + \frac{a^3}{3}\right) X_2 + \left(a^3 + \frac{a^3}{3}\right) X_3\right] =$$

$$\frac{a^3}{6 E I_3} (38 X_1 + 23 X_2 + 8 X_3)$$

$$\frac{d\,M_3\,M_3}{d\,X_2} = (2\,a^2 + 3\,a\,y + y^2)\,X_1 + (a^2 + 2\,a\,y + y^2)\,X_2 + (a\,y + y^2)\,X_3$$

$$\int_0^a \frac{d\,M_3\,M_3\,d\,y}{E\,I_3\,d\,X_2} = \frac{1}{E\,I_3}$$

$$\left[\left(2\,a^3 + \frac{3\,a^3}{2} + \frac{a^3}{3}\right)X_1 + \left(a^3 + a^3 + \frac{a^3}{3}\right)X_2 + \left(\frac{a^3}{2} + \frac{a^3}{3}\right)X_3\right] = \frac{a^3}{6\,E\,I_3}(23\,X_1 + 14\,X_2 + 5\,X_3)$$

$$\frac{d\,M_3\,M_3}{d\,X_3} = (2\,a\,y + y^2)\,X_1 + (a\,y + y^2)\,X_2 + y^2\,X_3$$

$$\int_0^a \frac{d\,M_3\,M_3}{E\,I_3\,d\,X_3}\,d\,y = \frac{1}{E\,I_3}$$

$$\left[\left(a^3 + \frac{a^3}{3}\right)X_3 + \left(\frac{a^3}{2} + \frac{a^3}{3}\right)X_2 + \frac{a^3}{3}\,X_3\right] = \frac{a^3}{6\,E\,I_3}(8\,X_1 + 5\,X_2 + 2\,X_3)$$

$$M_4 = (3a + y)\,X_1 + (2a + y)\,X_2 + (a + y)X_3 + y\,X_4$$

$$\frac{d\,M_4}{d\,X} = (3\,a + y),\ \frac{d\,M_4}{d\,X_2} = (2\,a + y),\ \frac{d\,M_4}{d\,X_3} = a + y,\ \frac{d\,M_4}{d\,X_4} = y$$

$$\frac{d\,M_4\,M_4}{d\,X_1} = (9\,a^2 + 6\,a\,y + y^2)\,X_1 + (6\,a^2 + 5\,a\,y + y^2)\,X_2 + (3\,a^2 + 4\,a\,y + y^2)\,X_3 + (3\,a\,y + y^2)\,X_4$$

$$\int_0^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_1}\,d\,y = \frac{a^3}{6\,E\,I}(74\,X_1 + 53\,X_2 + 32\,X_3 + 11\,X_4)$$

$$\frac{d\,M_4\,M_4}{d\,X_2} = (6\,a^2 + 5\,a\,y + y^2)\,X_1 + (4\,a^2 + 4\,a\,y + y^2)\,X_2 + (2\,a^2 + 3\,a\,y + y^2)\,X_3 + (2\,a\,y + y^2)\,X_4$$

$$\int_0^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_2}\,d\,y = \frac{a^3}{6\,E\,I_4}(53\,X_1 + 38\,X_2 + 23\,X_3 + 8\,X_4)$$

$$\frac{d\,M_4\,M_4}{d\,X_3} = (3\,a^2 + 4\,a\,y + y^2)\,X_1 + (2\,a^2 + 3\,a\,y + y^2)\,X_2 + (a^2 + 2\,a\,y + y^2)\,X_3 + (a\,y + y^2)\,X_4$$

$$\int_0^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_3} = \frac{a^3}{6\,E\,I_4}(32\,X_1 + 23\,X_2 + 14\,X_3 + 5\,X_4)$$

$$\frac{d\,M_4\,M_4}{d\,X_4} = (3\,a\,y + y^2)\,X_1 + (2\,a\,y + y^2)\,X_2 + (a\,y + y^2)\,X_3 + y^2\,X_4$$

Then $M_1 = y\,X_1$, and $\dfrac{d\,M_1}{d\,X_1} = y$

$$\int_o^a \frac{d\,M_1\,M_1}{E\,I_1\,d\,X_1}\,d\,y = \frac{a^3}{6\,E\,I_1}\,(2\,X_1)$$

$$M_2 = (y + a)\,X_1 + y\,X_2$$

$$\frac{d\,M_2}{d\,X_1} = y + a, \qquad \frac{d\,M_2}{d\,X_2} = y$$

$$\frac{d\,M_2\,M_2}{d\,X_1} = (y^2 + 2\,a\,y + a^2)\,X_1 + (y^2 + a\,y)\,X_2$$

$$\int_o^a \frac{d\,M_2\,M_2}{E\,I_2\,d\,X_1}\,d\,y = \frac{1}{E\,I_2}$$

$$\left[\left(\frac{a^3}{3} + a^3 + a^3\right)X_1 + \left(\frac{a^3}{3} + \frac{a^3}{2}\right)X_2\right] =$$

$$\frac{a^3}{6\,E\,I_2}\,(14\,X_1 + 5\,X_2)$$

$$\frac{d\,M_2\,M_2}{d\,X_2} = (y^2 + a\,y)\,X_1 + y^2\,X_2$$

$$\int_o^a \frac{d\,M_2\,M_2\,d\,y}{E\,I_2\,d\,X_2} = \left[\left(\frac{a^3}{3} + \frac{a^3}{2}\right)X_1 + \frac{a^3}{3}\,X_2\right]\frac{1}{E\,I_2} =$$

$$\frac{a^3}{6\,E\,I_2}\,(5\,X_1 + 2\,X_2)$$

$$M_3 = (2\,a + y)\,X_1 + (a + y)\,X_2 + y\,X_3$$

$$\frac{d\,M_3}{d\,X_1} = (2\,a + y), \quad \frac{d\,M_3}{d\,X_2} = a + y, \quad \frac{d\,M_3}{d\,X_3} = y$$

$$\frac{d\,M_3\,M_3}{d\,X_1} = (4\,a^2 + 4\,a\,y + y^2)\,X_1 + (2\,a^2 + 3\,a\,y + y^2)\,X_2 +$$

$$(2\,a\,y + y^2)\,X_3$$

$$\int_o^a \frac{d\,M_3\,M_3\,d\,y}{d\,X_1} = \frac{1}{E\,I_3}$$

$$\left[\left(4\,a^3 + 2\,a^3 + \frac{a^3}{3}\right)X_1 + \left(2\,a^3 + \frac{3\,a^3}{2} + \frac{a^3}{3}\right)X_2 + \left(a^3 + \frac{a^3}{3}\right)X_3\right] =$$

$$\frac{a^3}{6\,E\,I_3}\,(38\,X_1 + 23\,X_2 + 8\,X_3)$$

$$\frac{d\,M_3\,M_3}{d\,X_2} = (2\,a^2 + 3\,a\,y + y^2)\,X_1 + (a^2 + 2\,a\,y + y^2)\,X_2 + (a\,y + y^2)\,X_3$$

$$\int_o^a \frac{d\,M_3\,M_3\,d\,y}{E\,I_3\,d\,X_2} = \frac{1}{E\,I_3}$$

$$\left[\left(2\,a^3 + \frac{3\,a^3}{2} + \frac{a^3}{3}\right)X_1 + \left(a^3 + a^3 + \frac{a^3}{3}\right)X_2 + \left(\frac{a^3}{2} + \frac{a^3}{3}\right)X_3\right] = \frac{a^3}{6\,E\,I_3}\,(23\,X_1 + 14\,X_2 + 5\,X_3)$$

$$\frac{d\,M_3\,M_3}{d\,X_3} = (2\,a\,y + y^2)\,X_1 + (a\,y + y^2)\,X_2 + y^2\,X_3$$

$$\int_o^a \frac{d\,M_3\,M_3}{E\,I_3\,d\,X_3}\,d\,y = \frac{1}{E\,I_3}$$

$$\left[\left(a^3 + \frac{a^3}{3}\right)X_3 + \left(\frac{a^3}{2} + \frac{a^3}{3}\right)X_2 + \frac{a^3}{3}\,X_3\right] = \frac{a^3}{6\,E\,I_3}\,(8\,X_1 + 5\,X_2 + 2\,X_3)$$

$$M_4 = (3a + y)\,X_1 + (2a + y)\,X_2 + (a + y)X_3 + y\,X_4$$

$$\frac{d\,M_4}{d\,X} = (3\,a + y),\quad \frac{d\,M_4}{d\,X_2} = (2\,a + y),\quad \frac{d\,M_4}{d\,X_3} = a + y,\quad \frac{d\,M_4}{d\,X_4} = y$$

$$\frac{d\,M_4\,M_4}{d\,X_1} = (9\,a^2 + 6\,a\,y + y^2)\,X_1 + (6\,a^2 + 5\,a\,y + y^2)\,X_2 + (3\,a^2 + 4\,a\,y + y^2)\,X_3 + (3\,a\,y + y^2)\,X_4$$

$$\int_o^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_1}\,d\,y = \frac{a^3}{6\,E\,I}\,(74\,X_1 + 53\,X_2 + 32\,X_3 + 11\,X_4)$$

$$\frac{d\,M_4\,M_4}{d\,X_2} = (6\,a^2 + 5\,a\,y + y^2)\,X_1 + (4\,a^2 + 4\,a\,y + y^2)\,X_2 + (2\,a^2 + 3\,a\,y + y^2)\,X_3 + (2\,a\,y + y^2)\,X_4$$

$$\int_o^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_2}\,d\,y = \frac{a^3}{6\,E\,I_4}\,(53\,X_1 + 38\,X_2 + 23\,X_3 + 8\,X_4)$$

$$\frac{d\,M_4\,M_4}{d\,X_3} = (3\,a^2 + 4\,a\,y + y^2)\,X_1 + (2\,a^2 + 3\,a\,y + y^2)\,X_2 + (a^2 + 2\,a\,y + y^2)\,X_3 + (a\,y + y^2)\,X_4$$

$$\int_o^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_3} = \frac{a^3}{6\,E\,I_4}\,(32\,X_1 + 23\,X_2 + 14\,X_3 + 5\,X_4)$$

$$\frac{d\,M_4\,M_4}{d\,X_4} = (3\,a\,y + y^2)\,X_1 + (2\,a\,y + y^2)\,X_2 + (a\,y + y^2)\,X_3 + y^2\,X_4$$

$$\int_o^a \frac{d\,M_4\,M_4}{E\,I_4\,d\,X_4} = \frac{a^3}{6\,E\,I_4}(11\,X_1 + 8\,X_2 + 5\,X_3 + 2\,X_4)$$

$$M_5 = (4\,a + y)\,X_1 + (3\,a + y)\,X_2 + (2\,a + y)\,X_3 + (a + y)\,X_4 + y\,X_5$$

$$\frac{d\,M_5}{d\,X_1} = (4\,a + y),\quad \frac{d\,M_5}{d\,X_2} = (3\,a + y),\quad \frac{d\,M_5}{d\,X_3} = (2\,a + y),\quad \frac{d\,M_5}{d\,X_4} = (a + y),\quad \frac{d\,M_5}{d\,X_5} = y$$

$$\frac{d\,M_5\,M_5}{d\,X_1} = (16\,a^2 + 8\,a\,y + y^2)\,X_1 + (12\,a^2 + 7\,a\,y + y^2)\,X_2 + (8\,a^2 + 6\,a\,y + y^2)\,X_3 + (4\,a^2 + 5\,a\,y + y^2)\,X_4 + (4\,a\,y + y^2)\,X_5$$

$$\int_o^a \frac{d\,M_5\,M_5}{E\,I_5\,d\,X_1}\,d\,y = \frac{a^3}{6\,E\,I_5}(122\,X_1 + 95\,X_2 + 68\,X_3 + 41\,X_4 + 14\,X_5)$$

$$\frac{d\,M_5\,M_5}{d\,X_2} = (12\,a^2 + 7\,a\,y + y^2)\,X_1 + (9\,a^2 + 6\,a\,y + y^2)\,X_2 + (6\,a^2 + 5\,a\,y + y^2)\,X_3 + (3\,a^2 + 4\,a\,y + y^2)\,X_4 + (3\,a\,y + y^2)\,X_5$$

$$\int_o^a \frac{d\,M_5\,M_5}{E\,I_5\,d\,X_2}\,d\,y = \frac{a^3}{6\,E\,I_5}(95\,X_1 + 74\,X_2 + 53\,X_3 + 32\,X_4 + 11\,X_5)$$

$$\frac{d\,M_5\,M_5}{d\,X_3} = (8\,a^2 + 6\,a\,y + y^2)\,X_1 + (6\,a^2 + 5\,a\,y + y^2)\,X_2 + (4\,a^2 + 4\,a\,y + y^2)\,X_3 + (2\,a^2 + 3\,a\,y + y^2)\,X_4 + (2\,a\,y + y^2)\,X_5$$

$$\int_o^a \frac{d\,M_5\,M_5}{E\,I_5\,d\,X_3}\,d\,y = \frac{a^3}{6\,E\,I_5}(68\,X_1 + 53\,X_2 + 38\,X_3 + 23\,X_4 + 8\,X_5)$$

$$\frac{d\,M_5\,M_5}{d\,X_4} = (4\,a^2 + 5\,a\,y + y^2)\,X_1 + (3\,a^2 + 4\,a\,y + y^2)\,X_2 + (2\,a^2 + 3\,a\,y + y^2)\,X_3 + (a^2 + 2\,a\,y + y^2)\,X_4 + (a\,y + y^2)\,X_5$$

$$\int_o^a \frac{d\,M_5\,M_5}{E\,I_5\,d\,X_4}\,d\,y = \frac{a^3}{6\,E\,I_5}(41\,X_1 + 32\,X_2 + 23\,X_3 + 14\,X_4 + 5\,X_5)$$

$$\frac{d\,M_5\,M_5}{d\,X_5} = (4\,a\,y + y^2)\,X_1 + (3\,a\,y + y^2)\,X_2 + (2\,a\,y + y^2)\,X_3 + (a\,y + y^2)\,X_4 + y^2\,X_5$$

$$\int_0^a \frac{d\,M_5\,M_5}{E\,I_5\,d\,X_5}\,d\,y = \frac{a^3}{6\,E\,I_5}$$

$$(14\,X_1 + 11\,X_2 + 8\,X_3 + 5\,X_4 + 2\,X_5)$$

$$I_1 = 540$$
$$I_2 = 3\,240$$
$$I_3 = 10\,800$$
$$I_4 = 32\,400$$
$$I_5 = 81\,000$$

To simplify the numerical work, the factor, $36 = C$, is introduced. Then,

$$\frac{a^3\,C}{6\,E\,I_1} = \frac{300}{E}$$
$$\frac{a^3\,C}{6\,E\,I_2} = \frac{50}{E}$$
$$\frac{a^3\,C}{6\,E\,I_3} = \frac{15}{E}$$
$$\frac{a^3\,C}{6\,E\,I_4} = \frac{5}{E}$$
$$\frac{a^3\,C}{6\,E\,I_5} = \frac{2}{E}$$

$$D_1 = \int_0^H \frac{M\,d\,M}{E\,I\,d\,X_1}\,d\,y = \int_0^a \frac{M_1\,d\,M_1}{E\,I_1\,d\,X_1}\,d\,y +$$

$$\int_0^a \frac{M_2\,d\,M_2}{E\,I_2\,d\,X_1}\,d\,y \ldots\ldots\ldots + \int_0^a \frac{M_5\,d\,M_5}{E\,I_5\,d\,X_1}$$

Or, by making the proper substitutions, we get:

$$C\,E\,D_1 = 2\,484\,X_1 + 1\,050\,X_2 + 416\,X_3 + 137\,X_4 + 28\,X_5$$
$$C\,E\,D_2 = 1\,050\,X_1 + 648\,X_2 + 293\,X_3 + 104\,X_4 + 22\,X_5$$
$$C\,E\,D_3 = 416\,X_1 + 296\,X_2 + 176\,X_3 + 71\,X_4 + 16\,X_5$$
$$C\,E\,D_4 = 137\,X_1 + 104\,X_2 + 71\,X_3 + 38\,X_4 + 10\,X_5$$
$$C\,E\,D_5 = 28\,X_1 + 22\,X_2 + 16\,X_3 + 10\,X_4 + 4\,X_5$$

By multiplying the values of $E\,D_1$, $E\,D_2$, etc., which were found from the arch, by the factor, 36, we have:

$$C\,E\,D_1 = 2\,382\,000 - 20\,714\,X_1$$
$$C\,E\,D_2 = 6\,851\,000 - 14\,638\,X_2$$
$$C\,E\,D_3 = 6\,214\,000 - 7\,477\,X_3$$
$$C\,E\,D_4 = 6\,658\,000 - 5\,562\,X_4$$
$$C\,E\,D_5 = 6\,574\,000 - 4\,180\,X_5$$

We have now two sets of expressions for the same thing. By equating these we get the following group of simultaneous equations:

$$0 = -2\,382\,000 + 23\,198\,X_1 + 1\,050\,X_2 + 416\,X_3 + 137\,X_4 + 28\,X_5$$
$$0 = -6\,851\,000 + 1\,050\,X_1 + 15\,286\,X_2 + 269\,X_3 + 104\,X_4 + 22\,X_5$$
$$0 = -6\,214\,000 + 416\,X_1 + 296\,X_2 + 7\,653\,X_3 + 71\,X_4 + 16\,X_5$$
$$0 = -6\,658\,000 + 137\,X_1 + 104\,X_2 + 71\,X_3 + 5\,600\,X_4 + 10\,X_5$$
$$0 = -6\,574\,000 + 28\,X_1 + 22\,X_2 + 16\,X_3 + 10\,X_4 + 4\,184\,X_5$$

Solving these equations we get:

$$X_1 = 61$$
$$X_2 = 420$$
$$X_3 = 780$$
$$X_4 = 1\,167$$
$$X_5 = 1\,570$$

These are the thrusts to be sustained by the gravity section, and may now be used in place of the actual to compute the stresses in the gravity section.

The loads on the arches are:

$$P_1 - X_1 = 55$$
$$P_2 - X_2 = 48$$
$$P_3 - X_3 = 51$$
$$P_4 - X_4 = 30$$
$$P_5 - X_5 = 3$$

By comparing these with the loading which goes to the gravity section, it is seen that the arch carried nearly half the load at the top, but only about 6% half way down, and practically none at the bottom. However, any assistance near the top of a gravity dam is worth many times the same amount near the bottom. Table No. 3 gives the computation of stresses in the trapezoidal section included between two radial planes for both the case of reservoir empty and that of reservoir full. For the horizontal thrusts of water pressure, X_1, X_2. etc., just found, were used down to Elevation 70. Below this point the actual water pressures were used. In this table,

b = the breadth of the joint;

C_1 = the width of the up-stream edge of the joint;

C_2 = " " " down-stream edge of the joint;

r = " radius " " " " "

s_1 = " batter " up-stream face in the 10 ft. next above the joint;

s_2 = the batter of the down-stream face in the 10 ft. next above the joint;

a = the area of the horizontal joint $= \frac{(C_1 + C_2)\, b}{2}$;

W = the weight of all masonry above the joint, in terms of the weight of a cubic foot of masonry;

g = the distance of the center of gravity of the joint from its up-stream edge $= \frac{b\,(C_1 - 2C_2)}{3\,(C_1 + C_2)}$;

M = the moment of all the masonry above a joint about its up-stream edge;

n = the distance from the up-stream edge of a joint to the resultant for reservoir empty $= \frac{M}{W}$;

t = the actual thrust of the water against the 10-ft. layer next above a joint, in terms of the weight of a cubic foot of masonry;

X = the thrust of the water against the 10-ft. layer next above a joint which is carried by the gravity section (see the foregoing computation of the effect of arch action);

M_1 = the moment about the joint of all these loadings (X) which act above it;

v = the distance between the resultants for reservoir full and reservoir empty $= \frac{M_1}{W}$;

I = the moment of inertia of the joint about its center of gravity;

f_1 = the vertical stress, in pounds per square foot, at the up-stream edge when the reservoir is empty, =

$$\frac{156.25\ W}{a} + \frac{156.25\ W\,(g - n)\,g}{I};$$

f_2 = the vertical stress, in pounds per square foot, at the down-stream edge when the reservoir is empty, =

$$\frac{156.25\ W}{a} + \frac{156.25\ (g - n)\ (b - g)}{I};$$

f'_1 = the vertical stress, in pounds per square foot, at the up-stream edge of the joint when the reservoir is full, =

$$\frac{156.25\ W}{a} - \frac{156.25\ W\,(n + v - g)\,g}{I}.$$

f'_2 = vertical stress, in pounds per square foot, at the down-stream edge of the joint when the reservoir is full, =

$$\frac{156.25\ W}{a} + \frac{156.25\ W(n + v - g)\ (b - g)}{I}$$

In discussing Table No. 3 it should be noted that with this treatment of the subject there is no question of whether or not the resultants fall within the middle third. That condition applies only when the horizontal sections are rectangular. However, to show the effect of the arch action upon the position of the resultants, they are plotted in Fig. 10. The line $a—a$ shows the position of the resultants for reservoir full if the gravity section receives no assistance from the arch form. The adjacent line shows the position of the resultants for reservoir full when the gravity section is assisted by the arches.

The last four columns of Table No. 3 are of principal interest. They show no tension and no compression greater than is safe for the excellent masonry used in the dam. At the toe the stress is about 35 000 lbs. per square foot. There are two reasons why this stress can probably never be developed. The lower 50 ft. of the dam is in a deep, narrow, crooked cañon, and if at the toe a horizontal straight line is drawn at right angles to the dam it will soon run into the solid granite rock of the cañon. This is shown very well in Fig. 2, Plate XVII. It is also probable that the masonry of the dam itself will bridge across the narrow cañon, delivering much of its weight to the side walls.

The position of the resultants for reservoir full and reservoir empty, as shown by Table No. 3, is shown in Fig. 10.

The line a–a shows the position of the resultants for reservoir full if the gravity section receives no assistance from the arches.

The assumption was made, in the beginning of the analysis, that the arches were loaded uniformly, and that their deflection increased uniformly from zero at the abutments to a maximum at the middle. We have now to show that the assumption was warranted.

By substituting 61 for X_1 and 36 for C, in the equation giving the deflection of the top arch, we get

$$D_1 = \frac{31\ 100}{E}.$$

This is the deflection at the middle of the dam. By the assumption, the deflections, at points on the arch, one-fifth, two-fifths, three-

TABLE No. 3.

Elevation of joint.	b Breadth of joint.	C_1 Width of up-stream edge of joint.	C_2 Width of down-stream edge of joint.	r Radius of down-stream edge of joint.	S_1 Batter of up-stream face, in 10 ft. above the joint.	S_2 Batter of down-stream face, in 10 ft. above the joint.	a Area of horizontal joint.	W Total weight of masonry above the joint.	g_1 Distance of center of gravity of joint from up-stream edge.	M Total moment of masonry above up-stream edge.	n Distance from up-stream edge to resultant, reservoir empty.	t Actual thrust of water on 10-ft. layer above joint.	X Thrust of water on 10-ft. layer carried by gravity section.	M_1 Moment of all X's above joint.	v Distance between results, reservoir empty and reservoir full.	I Moment of inertia of joint.	Reservoir Empty. f_1 Stress on up-stream edge.	Reservoir Empty. f_2 Stress on down-stream edge.	Reservoir Full. f'_1 Stress on up-stream edge.	Reservoir Full. f'_2 Stress on down-stream edge.
190..	18	1.002	0.956	381.89	0	....	17.62	498	8.93	4 401	8.93	115	61	488	0.99	484	4 380	4 380	2 970	5 800
180..	22	1.002	0.946	377.89	0	4.00	21.43	689	10.89	6 844	9.22	116	100	1 598	2.32	865	7 280	2 720	4 140	5 920
170..	26	1.002	0.936	373.89	0	4.00	25.20	922	12.85	9 114	9.90	156	140	3 908	4.23	1 423	9 550	1 790	4 490	7 064
160..	31.5	1.002	0.923	368.53	0.14	5.36	30.32	1 199	15.58	13 212	11.02	196.1	180	7 818	6.58	2 518	11 020	1 300	3 500	8 940
150..	37	1.002	0.910	363.17	0.14	5.36	35.37	1 528	18.19	18 952	12.40	236.9	220	13 728	8.99	4 068	12 290	870	2 730	10 880
140..	44	1.004	0.894	356.77	0.6	6.40	41.76	1 914	21.58	27 728	14.48	276.9	260	22 038	11.52	6 728	13 570	490	2 520	11 970
130..	51	1.005	0.878	350.37	0.6	6.40	48.02	2 363	24.93	39 464	16.70	317.4	300	33 148	14.04	10 373	14 680	360	2 230	13 380
120..	58	1.007	0.862	343.97	0.6	6.40	54.20	2 874	28.25	54 529	18.97	358.1	348	47 498	16.53	15 180	15 800	340	1 890	15 020
110..	65.33	1.008	0.845	337.24	0.6	6.73	60.53	3 447	31.71	73 732	21.39	398.9	389	65 530	19.02	21 438	16 930	370	1 780	16 440
100..	72.66	1.01	0.828	330.51	0.6	6.73	66.77	4 084	34.92	97 211	23.80	440.1	430	87 663	21.47	30 320	17 580	680	1 800	17 940
90..	81.66	1.018	0.809	323.	1.486	7.514	74.39	4 789	39.31	130 021	27.15	481.5	480	114 343	23.88	41 154	18 630	890	1 570	19 200
80..	91.08	1.018	0.79	315.5	1.927	7.5	82.84	5 573	43.63	172 518	30.96	524.0	523	146 088	26 21	56 661	18 970	1 440	1 400	20 550
70..	100.51	1.023	0.771	308.	1.927	7.5	90.16	6 436	47.95	228 590	34.75	567.4	566	183 178	28.47	75 084	18 550	1 950	1 270	21 960
60..	109.94	1.028	0.753	300.5	1.927	7.5	97.90	7 376	52.15	283 976	38.61	611.2	611	226 208	30.67	97 440	20 060	2 580	1 140	23 550
50..	119.36	1.033	0.734	293.	1.927	7.5	105.45	8 393	56.32	354 319	42.22	655.5	655	275 558	32.83	124 580	20 740	3 140	1 230	24 940
40..	128.79	1.037	0.715	285.5	1.927	7.5	112.83	9 484	60.38	485 094	45.88	699.8	699	331 683	34.97	155 270	21 440	3 710	1 290	26 550
30..	138.22	1.042	0.696	278.	1.927	7.5	120.11	10 649	64.52	527 242	49.52	744.3	744	395 023	37.10	188 790	22 340	4 150	1 250	28 250
20..	147.65	1.047	0.678	270.5	1.927	7.5	127.85	11 886	68.57	631 804	53.12	789.7	790	466 033	39.22	226 940	23 230	4 690	1 280	30 000
10..	157.07	1.052	0.659	263.	1.927	7.5	134.42	13 195	72.58	747 830	56.68	835.4	835	545 168	41.31	271 840	24 020	4 960	1 300	31 720
0..	166.5	1.057	0.640	255.5	1.927	7.5	141.27	14 573	76.43	877 255	60.20	881.6	882	632 858	43.43	320 800	24 900	5 780	1 340	33 540
− 10..	175.93	1.062	0.621	248.	1.927	7.5	148.04	16 020	80.28	1 020 165	63.67	928.1	928	729 658	45.54	373 800	25 800	6 330	1 340	35 470

fifths and four-fifths of the distance from the middle toward the abutment, will be $\frac{24\,800}{E}$, $\frac{18\,600}{E}$, $\frac{12\,400}{E}$, and $\frac{6\,200}{E}$, respectively.

By substituting the values of X_1, X_2, X_3, X_4 and X_5, in the equations for the deflection of the vertical beam or gravity section, we get $D_1 = \frac{31\,100}{E}$, which checks the values just found for the middle of the top arch.

If the base of the dam follows the line *a–b–c*, Fig. 7, then at the points one-fifth, two-fifths, three-fifths and four-fifths of the distance from middle toward the abutments, the base will be at Elevations 85, 115, 145 and 175. Computing the deflection of the tops of the gravity sections loaded with X_1, X_2, etc., the bases of which are at these elevations, the deflections are:

$$\frac{25\,000}{E}, \quad \frac{16\,000}{E}, \quad \frac{8\,000}{E} \text{ and } \frac{800}{E}.$$

These agree very well with those above, except at the three-fifths and four-fifths points, where the deflection of the beam is much less. This means that the gravity section may take more load than X_1 and X_2, but it is abundantly strong to carry all the water pressure and more, and it seems that the assumption was warranted, especially as no account has been taken of the stiffness of the fixed abutment of the arch, which would tend to make the deflection of the arch less near the abutments.

It will be noticed that it has not been necessary to assign an absolute value to E; the foregoing analysis would have little value had it been necessary to do so, for the modulus of elasticity of masonry is, not only different for each piece of work, but is different for different ages of the same mass.

It has been assumed, simply, that the modulus is the same, both for horizontal and vertical directions. There appears to be no reason why this should not be so.

The value of E probably lies somewhere between 2 000 000 and 4 000 000 lbs. per square inch, or say 3 000 000. This, in terms of the weight of a cubic foot of masonry and a square foot, is 2 764 000. If this value be substituted in Equation $D_1 = \frac{31\,100}{E}$, we get $D_1 = 0.011$ ft. for the deflection at the top and middle point of the dam.

Thus far, only the forces of water pressure and gravity have been considered as acting upon the dam. Besides the stresses induced by these forces, there will be internal stresses caused by the change of volume of the mortar in setting, the building of portions of the dam more rapidly than others, and certain portions in cold weather and others in warm weather.

Of these stresses, probably those due to temperature changes are much the greatest. The dam has been built nearly continuously, winter and summer, so that it is practically impossible to set the range of temperature which will produce stress. When the reservoir is full, about 30° Fahr. is as great a change of temperature as can be expected. This would tend to make the arch in summer carry more load than has been attributed to it by the analysis, and less in winter, supposing that the dam is always at a uniform temperature. Should the dam be cooler on the down-stream face than on the other, which will nearly always be the case in winter, the effect would be to throw more load on the arch, thus neutralizing the effect of the winter condition of the arch. Likewise, a warm down-stream face would neutralize the effect of the summer lengthening of the arch.

If the dam should stand through a cold winter with no water against its up-stream face, cracks might be expected in the upper part, which was built for the most part in summer. This is the common experience with straight dams.

The curved form, having greater flexibility, would tend to reduce the number and size of the cracks, and, in a dam like the Bear Valley Dam, the arch would probably be flexible enough to prevent them entirely. This cannot be expected in the Lake Cheesman Dam, but, no doubt, it will prevent any temperature cracks when the reservoir is full.

A theoretical analysis of stress is always open to more or less doubt, and probably the best test of a design is a comparison with precedents whenever it is possible.

Fig. 11 shows superimposed profiles of several dams which are comparable with the Lake Cheesman Dam, as follows:

The Villar Dam, in Spain, built in 1870 to 1878, of rubble masonry, and curved to a radius of 440 ft.

The Chatrain or Tache Dam, in France, built in 1888 to 1892, of rubble masonry, and curved to a radius of 1 312 ft.

The Furens Dam, in France, built in 1862 to 1866, of rubble masonry, and curved to a radius of 828 ft.

The Ban Dam, in France, built in 1867 to 1870, of rubble masonry, and curved in plan.

The Periyar Dam, in India, built in 1888 to 1895, of concrete, and straight in plan.

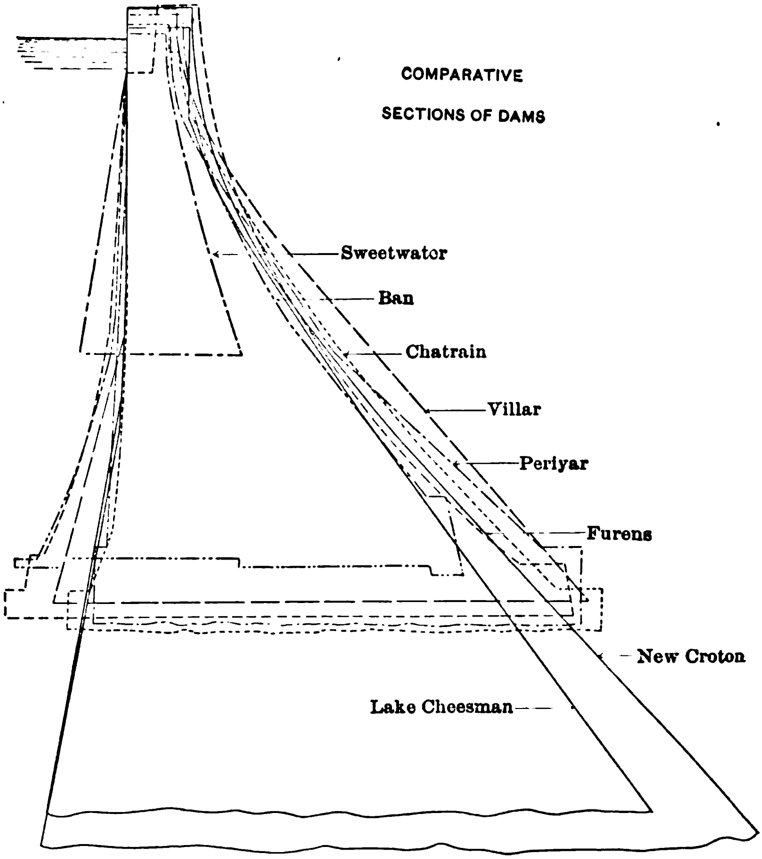


FIG. 11

The Sweetwater Dam, in California, built in 1887 and 1888, of rubble masonry, and curved to a radius of 222 ft.

The profiles shown in broken lines in Fig. 11 are all of dams which have been built and have been subjected to pressure for some years, and are the best precedents existing. The five first named are

the highest dams in the world which have been subject to test. All except the Periyar are curved in plan. The Sweetwater, however, is the only one in which the designers relied on the arched form for strength. In this case the arched form is the main reliance, although the dam has considerable resistance as a gravity section. The adopted profile of the Lake Cheesman Dam is shown by a full line. Compared with all but the Sweetwater Dam, it seems rather slender. There are, however, three conditions which offset this:

The lower portion shown in the profile is little more than a plug of a narrow cañon. The length of this plug, in a direction transverse to the dam, is two or three times its breadth, and can hardly be conceived to develop the stresses which might be expected in a dam the base of which is as long as its top. The masonry being used is probably heavier and better than that in any of the five dams the profiles of which lie outside it. Also, it is curved to a smaller radius than any of these dams.

The profile of the New Croton Dam is also shown in Fig. 11. This can hardly be called a precedent, for the dam is not completed, and, of course, has not been tested. The design, however, has been before the engineering profession for a number of years and has been approved by many men of the best judgment.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE BREAKWATER AT BUFFALO, NEW YORK.

Discussion.*

By Messrs. G. H. Raymond and George E. Fell.

Mr. Raymond.

G. H. Raymond,† Esq. (by letter).—The writer has read with pleasure this admirable contribution to the history of the Buffalo Breakwater, and although he cannot discuss the paper from a technical standpoint, yet, having been much interested in the proposed 1 000-Ton Barge Canal proposition for some years, he has been especially impressed with the magnitude of the Buffalo breakwater and its bearing on the commercial future of the State of New York and the nation at large.

It is a strange fact that the building of this breakwater has been the greatest factor in bringing about the ratification of the canal referendum at the last election.

When the history of this movement for canal improvement is written, it will be made clear that the engineering ability of Major Thomas W. Symons, U. S. A., in designing the breakwater, and the care exercised by Assistant Engineers Quintus and Low in carrying out the plans, have been of the greatest value to the canal proposition.

The value of the breakwater as a harbor protection was evident, but the problem of canal improvement needed some great impetus to impress its value on the people of the State.

The possible future of the eastern end of Lake Erie, as a point for making iron and steel, was recognized, but the harbor conditions at

* Continued from January, 1904, *Proceedings*. See November, 1903, *Proceedings*, for paper on this subject by Emile Low, M. Am. Soc. C. E.

† Secretary, Canal Enlargement Committee.

Buffalo were such that it was practically impossible to secure a sufficient area of land, adapted to an enormous steel plant and also having deep-water facilities for the ever-increasing capacity of lake craft. Mr. Raymond.

The practical completion of the breakwater was in sight when a body of men, very largely interested in the iron and steel business, was looking for a site on the shore of Lake Erie where adequate rail connections and suitable deep-water facilities could be secured. They were also looking naturally for a cheap water route, for their products to the seaboard, and for eastern and foreign ores to be moved to their plant.

The deep-water facilities to be furnished by the breakwater, and the splendid railroad accommodations at Buffalo, coupled with the possible cheap water rate for foreign ores and those from Lake Champlain, together with the cheapest possible rate to the seaboard on their output, based on the active agitation for the 1 000-Ton Barge Canal, induced these men to locate at Stony Point, inside the breakwater.

This enormous plant, wherein is being invested about $40 000 000, furnished the one great object lesson to show the people of the State what a magnet cheap transportation offered to the future iron and steel business of this country, and that the 1 000-Ton Barge Canal was needed to round out the State's manufacturing possibilities.

There are numberless arguments in favor of the barge canal, and its ratification at the polls, by the largest majority ever given to any similar proposition in the history of the State, is evidence of the thorough appreciation of its future value; but one of the strongest arguments was the manufacturing possibilities along its length, through the centering of iron and steel interests along the Niagara Frontier.

The Buffalo Breakwater alone made it possible to show the people that the iron and steel business would come to them if given proper encouragement, and to its building may very largely be ascribed the final success of the canal.

The Buffalo Breakwater and the 1 000-Ton Barge Canal are the two greatest propositions, in their respective lines, in the world, and it is a remarkable coincidence that they should be so intimately associated in location and in their effect on the future commercial history and prosperity of the State of New York.

The completion of the Buffalo Breakwater, the building of the 1 000-Ton Barge Canal and the construction of a ship canal around the rapids of the Niagara River, which latter project is now being actively urged by Colonel Thomas A. Bingham, will insure forever the commercial supremacy of the State of New York and bring untold benefit to the entire territory tributary to the Great Lakes.

GEORGE E. FELL, Esq. (by letter).—The writer was engaged on the improvement of Buffalo Harbor, as U. S. Assistant Engineer, under Captain F. Harwood, Corps of Engineers, U. S. A., and presents the following historical notes in relation to the early stages of the work. Mr. Fell.

Mr. Fell. The construction of this great system of breakwaters was commenced in the spring of 1869. The construction under water consisted of 34 x 50-ft. cribs, of 12 x 12-in. hemlock. The lower courses, up to within 3 ft. of the water surface, were of hemlock. Above this level, the superstructure consisted of continuous 12 x 12-in. pine timbers, to a height of 8 ft. above the standard level of the water. This standard was established by the writer, under Captain Harwood's direction, by a fixed bench-mark on the lighthouse, 16.947 ft. above ordinary low-water level of the lake at the time. This level was adopted arbitrarily and has been used in all subsequent observations. During the early years of the work the stage of the water was noted two or three times a day. These records, if in existence, should be of great value in determining the variation of the lake level.

The following notes, relative to the sinking of the first crib and other initial work, are taken from the writer's diary.

Preliminary arrangements for laying out the work were made on May 20th, 1869, and the lines of the south and north breakwaters were marked by buoys. On June 4th, the contractors had built Crib No. 1 to the full depth of twenty-three courses. On June 7th, at the site of Crib No. 1, six piles were driven, in the shape of the letter L, with the interior angle facing "up current" so that the crib would be held securely when floated into position.

The crib was towed to position during the night of June 8th, by moonlight. The crib was placed so that the proper corners fitted into the angles formed by the L-shaped group of piles and then sunk by filling it with stone. To align this crib, lanterns were placed on the line buoys.

Cribs Nos. 2 and 3 were built and placed in position in a similar manner. The placing of cribs was continued during the summer of 1869, although the season was exceptionally stormy, so that the work was prosecuted with difficulty, as will appear from the following instances:

On July 19th, Crib No. 5 was placed in line and properly secured. On July 21st, after about 200 cords of stone had been placed in the crib, a sudden southwest gale carried it away or broke it into two pieces, so that fifteen courses were carried ashore.

On September 29th, Crib No. 11, which had been sunk on September 27th, was carried ashore.

On November 18th, Crib No. 12 was washed ashore. Gales followed each other in quick succession, and disaster after disaster resulted, the short length of completed breakwater not affording sufficient lee for security in the work of construction. On October 23d, the last crib for the season was placed in line, making a length of 550 ft. of work for the season of 1869.

The season of 1870 was characterized by calm weather, a remarkable contrast to that of 1869. Crib after crib was placed in position, and the

breakwater became at once a great boon to the lake mariner in affording a safe lee in stormy weather. Mr. Fell.

As to the foundation conditions, Mr. Low says:*

"As the lake bottom of the area adjacent to the north end of the breakwater is generally rocky, overlaid with a thin layer of sand, no apprehension seems to have been felt in placing the cribs directly thereon; in fact, it is doubtful if any extended examination of the bottom, along the line of the proposed work, was made or considered necessary at the time."

As far as any extended examination of the lake bottom was concerned, this is true. Partial examinations, however, had been made by the writer, who began his work without previous knowledge or data to guide him.

The first attempts were made by the use of augers attached to gas pipes of varying lengths, the pipes being coupled, as usual, by screw sleeves. The pipes were prevented from turning at the joints by inserting ½-in. iron pins into holes drilled through each pipe and sleeve. A common auger was first used, and found unserviceable; a "worm" auger was then tried, with more success, but what is termed a "pod" auger gave the best results. In carrying on the boring operations two small scows were anchored in position close to each other, and a connecting platform laid over the intervening space. The augers were operated from this platfrom. The greatest penetration obtained was about 8 ft. through very soft clay. In gravel it was with great difficulty that any penetration, beyond a few feet, could be made. The augers, which were from 2 to 3 ins. in diameter, were too weak to withstand the strain applied and broke continually. In several instances the pipes were twisted out of shape. The work progressed slowly in any material excepting very soft clay. Heavy weights were attached to the pipe in order to force the auger to penetrate the strata, but without appreciable success. The only means of judging of the character of the material was from the sound made by the pipe in boring. Observations made in this manner were found to be unreliable.

In January, 1872, the writer made more extended investigations, of the character of the bottom material, through the ice. For this purpose there was used extra heavy gas pipe with an outer diameter of 2 ins. and an inner diameter of 1 in. and in sections from 5 to 8 ft. long. These lengths were joined with ordinary sleeves. The lower or penetrating end of the pipe was furnished with a sharpened steel shoe, the inner diameter of which, for about ½ in. of length, was a trifle smaller than the internal diameter of the pipe. This shoe was attached to the pipe so as to prevent jamming of the threads of the screw in driving. A hardened driving head was also provided.

For the purpose of driving, pulling and handling the pipe, a hand-power pile-driver was constructed for use on the ice. It was provided

* *Proceedings*, Am. Soc. C. E. for November, 1903, p. 959.

Mr. Fell. with runners so as to be more easily moved. A horse was kept on hand to move it, an absolute necessity when the snow was heavy. A 175-lb. cast-iron hammer was used for driving. Operations with this apparatus were conducted with great success, and the bottom of the lake was examined to the rock bed. In all cases the inside of the pipe was partially filled with the material forming the lake bottom. After the pipe was raised the shoe was removed and the contents of the pipe forced out with a rod which closely fitted the inside of the pipe. In driving, the different velocities of the pipe in penetrating the various strata indicated their relative densities (or resistances), the depths being also noted. As the pipe, when withdrawn, contained a sample of the material, the character of each stratum was known.

Owing to the cold weather, the contents of the pipe froze quickly; so that it was necessary to provide a stove, protected by a tent, and to use hot water for thawing out the pipe. The power afforded by the windlass attached to the driver was sometimes insufficient to withdraw the pipe; when this was the case various combinations of 8-in. and 12-in. pulley blocks were used in connection with the windlass, which was manned by five men. This additional power was required in cases where the pipe had penetrated sand and gravel in varying proportions. The average depth of water at the site of the work was 27 ft. The greatest penetration of the pipe was 22 ft. through red clay to the solid rock. The greatest length of pipe filled with material was 20 ft. These borings showed that the foundation of the cribs to be sunk during the season of 1872 would be in soft clay, and that considerable settlement might be expected. Therefore, special precautions were taken to keep the cribs in line by piling heavily, and the superstructure was built up to the full height. Toward the close of the season of 1872, however, this foundation showed evidence of serious weakness, as will appear from the following occurrence.

On September 29th, 1872, a violent southwest gale set in, and increased in fury during the following night. Up to 6 P. M. on this day the work was intact, but on the morning of September 30th, it was discovered that the whole of the addition of the season of 1872 had been displaced and had settled to a considerable extent. Cribs Nos. 42 to 47 had settled so that the top of their superstructure, instead of being 8 ft. above water, was in some places 2 ft. below water. The cribs had also worked out of line to a considerable extent. This disaster emphasized the necessity for a thorough examination of the bottom of the lake on the line of the proposed extension of the breakwater.

The following is a description of a plant used for examinations of the lake bed in the summer of 1873 on surveys for the Harbor of Refuge at Cleveland, Ohio. It consisted of a self-propelling scow and driver, which had formerly been used for driving stakes or poles

for fish nets. The scow was about 30 ft. long, 12 ft. wide and 2 ft. deep. At the stern was a central longitudinal open well, 10 ft. long and 1.5 ft. wide, in which a paddle wheel was placed. A small upright engine and boiler of about 6 H.-P. was used for propulsion and operating the boring apparatus. A 413-lb. hammer was used in driving. With this plant, borings were made in water from 24 to 37 ft. deep, and a penetration of 20 ft. made through shingle, quicksand and blue clay. In these depths it was found that there was considerable vibration of the pipe, indicating the desirability of using an outer pipe of larger diameter. The cost of operating this plant was $30.50 per day. Mr. Fell.

During the spring and summer of 1874 a survey of the harbor at Buffalo was made by the writer, under the direction of Major Harwood, for the Board of Engineer Officers of 1873–74. The plant used for ascertaining the character of the lake bed was designed by the writer as an improvement on that used at Cleveland. It was a self-propelling "steam rod driver," and consisted of a scow 40 ft. long, 12 ft. wide and 3 ft. deep, drawing 18 ins. of water. It was provided with a pile-driver, 28 ft. high, placed at one end, a propelling wheel, working in an open well, at the center, and a steam engine at the other end. The steam engine was used for propelling the scow and for operating the hammer used in driving the pipes. The rod driver was built at Buffalo and cost $2 600.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

METHOD USED BY THE RAILROAD COMMISSION, OF TEXAS, UNDER THE STOCK AND BOND LAW, IN VALUING RAILROAD PROPERTIES.

Discussion.*

By Messrs. F. LAVIS and W. H. COVERDALE.

Mr. Lavis. F. LAVIS, Assoc. M. Am. Soc. C. E.—As to the low valuation of some of the roads mentioned by Mr. Corthell, the speaker's experience, based on very close estimates of some projected lines in Northern Texas, estimates based on actual final location lines, and very careful examination of the ground, leads him to believe that Mr. Corthell's statement, that the valuations of the Commission were apt to be low, is correct.

The Texas State Railroad Commission, while not, perhaps, absolutely infallible, is, the speaker believes, one of the most efficient in the country. Texas has led all the other States, in miles of new railroad built, for several years past, and it is fortunate for the railroads, as well as for the State, that the laws relating to the railroads and the administration of them has been so efficient, and notwithstand-

* Continued from February, 1904, *Proceedings*. See January, 1904, *Proceedings*, for paper on the subject by R. A. Thompson, M. Am. Soc. C. E.

ing the remarks, as to the courage of promoters of railroad lines in Texas, all the older roads are seizing every opportunity to establish themselves in advantageous locations. Mr. Lavis.

The general character of the lines built in recent years shows that there is a marked departure from the older methods of location and construction. Where possible, with any reasonable, or even considerable, expenditure, the maximum grades are not greater than 0.5 or 0.6%, compensated for curvature, which latter seldom exceeds 4 degrees.

A recent law compels all existing steam railroads to install an interlocking plant at all grade crossings with other steam roads, the expense, both of installation and maintenance, to be borne equally by the two roads. Where a new road, however, proposes to cross a road already existing, the expense has to be borne entirely by the new road, provided the Railroad Commission decides that a separated crossing at the point in question is not practical, and it is somewhat difficult to demonstrate this to the present commission. New railroads however, can well afford to spend as much as from $25 000 to $30 000 to avoid the expense of the interlocking plant and its maintenance.

W. H. Coverdale, Assoc. M. Am. Soc. C. E.—Although it may seem to be a far cry from the recent tragic death of a London promoter and the no less pathetic situation now confronting the United States Shipbuilding Company to the subject-matter of this paper, yet the fact is that these seemingly diverse matters are but different effects of the mushroom growth which is called over-capitalization. On one hand, there is unrestricted and perhaps unlawful development, resulting in ruin; on the other hand, there is so rigorous a use of the pruning knife that the normal growth is stunted. Mr. Coverdale.

The very first sentence in Mr. Greene's little book on "Corporation Finance" is that a business man or firm must borrow money. With the individual, as with small firms and manufacturers in many lines, the loan may take the form of commercial paper; with the railroad, it generally consists of a mortgage. The regulation of the amount and character of such mortgage is one of the most important matters upon which definite legislation is needed.

Those engineers who have been identified with railroads are doubtless aware that within the last fifty years railroad commissions have been established in various States which deal, but by no means exclusively, with this matter.

These commissions now exist in New York, Massachusetts, Maine, New Hampshire, Vermont, Connecticut, Rhode Island, Pennsylvania, Ohio, Kentucky, Michigan, Wisconsin, Minnesota, North and South Dakota, Nebraska, Illinois, Iowa, Missouri, Texas, Arkansas, California, Virginia, Georgia, North and South Carolina, Tennessee, Alabama, Mississippi, Louisiana and Florida.

Mr. Coverdale. Seventeen States have no railroad commissions. Many of these commissions are mandatory, but some are merely advisory, and, indeed, the latter, in some instances, have shown themselves quite as proficient as the mandatory commissions holding greater legal power.

The Massachusetts Commission, which is advisory, only, has developed along broad lines, and its efficiency is well known. The Texas Commission, whose methods are under discussion, is mandatory, and is also well and favorably known. All these commissions deal with questions of public utility and convenience; questions of rates and traffic; questions of accounts, of arbitration, and in some cases of capitalization.

In addition to the State commissions there has been, since 1887, an Interstate Commerce Commission. This Commission devotes much time to rates and tariffs, and has done much to better conditions by doing away with pooling agreements and abolishing the system of secret rebates. Its functions, however, have been limited, and in some cases curtailed, by Supreme Court decisions relative to the intent of the Legislative Act under which it operates, and the main question of absolute control of railroad capitalization is, therefore, broadly speaking, untouched.

When it is considered that there are some forty-nine State governments exercising authority over the railroads of this country, the folly of looking to such diverse interests for harmonious and concerted action is seen. When it is considered, further, that one railroad property may extend over several States, and be subject to a new set of regulations and laws every time its tracks cross a State line, something is seen of the inconvenience and danger, even of the existing conditions. The word "danger" is used because a multiplicity of conflicting laws means an observance of none. When it is realized that only a portion of the traffic of a railroad can be controlled by State legislation, namely, the business originating and terminating within the State's borders, and that even the import and export traffic on through billing to and from interior points is not affected by the rulings of the Interstate Commerce Commission, it is seen that the present methods of control are inadequate and that evasions of the laws may be made with ease.

The present conditions, although in many respects unsatisfactory, mark substantial progress over those obtaining a few decades ago.

The years from 1850 to the beginning of the War marked the rapid growth of railroads in the Middle West, and the consolidation into trunk lines of the various smaller companies throughout the more thickly populated Eastern States. In those days the railroad was, in name and in fact, a private corporation operating without restrictions as to rates and methods. To-day the railroad is a public-service cor-

poration, and as such is in a measure subject to Government restrictions as to rates of traffic, public convenience, and publicity of operation. Mr. Coverdale.

In 1868 to 1872, during which years many of the western roads were constructed, the over-capitalization of these new lines was such that, notwithstanding Government land grants and money bonuses, disaster was not averted in the panic of '73.

The lesson learned then has not been forgotten, and the conservatism of to-day is substantial in character when compared with past conditions.

Disregarding the possibility of Government ownership or control of railroads, as too radical a departure from present conditions, and considering only Government supervision in all matters, including traffic rates and capitalization, and proceeding, also, upon the basis of rates which competitive traffic will bear, the question may now be asked: "Wherein consists the security of a railroad mortgage, and what assets may with propriety be considered as collateral therefor?"

In answering this question it is necessary to keep in mind the essential difference between a mortgage on real estate or on a manufacturing plant and a mortgage on railroad property. Land has a real value which may readily be ascertained, and its value as a mortgage security is that percentage on its market value which can be obtained for it at a forced sale; a manufacturing concern has also real value in such assets or real estate, plant, stock and finished product, and such a property should wreck for more than the amount of its outstanding obligations.

A railroad, it is true, has some real assets in the way of land, roadbed, buildings, and rolling stock, but it produces from this property nothing but that intangible, highly perishable commodity called transportation; it must operate even at a loss to prevent utter ruin; it cannot be devoted to other uses; it cannot be sold under foreclosure because its use is so restricted, and purchasers, therefore, few, but must generally be reorganized upon a more conservative basis, which means a loss to security holders.

A railroad mortgage, therefore, is secured only in part by its physical assets, notwithstanding the legal phraseology on the bond, and in part by its franchises and special privileges which contribute to its earning power no less than do its rolling stock and track.

Inasmuch as an *ex post facto* law has never been in general favor, it seems improbable that a readjustment in capitalization of existing roads could be made by Government authority, except at times of reorganization. At such times, with full operating statistics available, a fair valuation could be made in the following manner: Take the average yearly gross earnings and deduct therefrom the average operating expenses plus a proper amount for annual maintenance, taxes and betterments;

Mr. Coverdale. then, as a reserve fund, set aside such amount as will in the course of a few years provide a surplus against fluctuations of business, and the balance, capitalized, will represent the amount of securities which the property is worth.

By deducting from this sum the physical cost or value of the property, the proper value of the franchises, good will, or earning capacity is secured.

For example, take a railroad earning a gross income of \$10 000 000 per year. Such a road in Texas would be 2 000 miles long, as the average gross earnings of railroads in that State are about \$5 000 per mile. Deduct now 70% for operation, maintenance and taxes, which, again, fairly represents actual conditions, and there remains a balance of \$3 000 000.

Out of this sum set aside 5% of the gross earnings, or \$500 000, for reserve fund, and there is a balance of \$2 500 000.

Capitalizing this balance at 5% gives a total of \$50 000 000, which represents the total value of the property. The average cost of construction and equipment per mile, as determined by the Texas Commission, is about \$16 000, so that the physical value of the railroad would be \$32 000 000, leaving an actual value of \$18 000 000 to be ascribed to franchises and earning power.

This total valuation would be at the rate of \$25 000 per mile, as against \$46 691 per mile, which was the average in Texas in 1900, just prior to the act under which the Commission was created; and, as against \$16 120 per mile, which is the average for all the Texas railroads which the Commission has valued.

Such a method is conservative when compared with uncontrolled capitalization, and it approximates actual conditions more nearly than the restricted method which considers physical values only.

The foregoing figures represent both bonds and stock, and for two reasons: The first is that the Texas Commission figures include both classes of securities; and the second is that railroad stocks should have an investment value rather than a speculative value.

In the case of new roads, where no earning statistics are available, these could be estimated, on a conservative basis, from adjacent roads, or they could be omitted entirely and a temporary or partial valuation made on the cost of construction. Such valuation should be supplemented on the more liberal basis as soon as the earning capacity of the road is demonstrated; and in valuations of both old and new roads provision should be made for increase of capitalization commensurate with growth of earnings.

The speaker has spent considerable time in Texas on railroad work, and is acquainted, superficially, with the methods of the Commission in the matter of valuations.

He had the pleasure of being on a railroad inspection trip in 1902 with the author, and was much impressed with the thoroughness and

care evinced, even in matters of small detail. The Texas Commission has had a wholesome effect on Texas railroading, and is popular both with the railroads and the public. Mr. Coverdale.

In closing, the speaker wishes to note three pertinent items:

First.—The Texas railroads constructed prior to the passage of the act of 1893 seem to have an advantage over those built since, as their capitalization is unaffected. Perhaps this is a fallacy, however, as more than 90% of them were in the hands of receivers when the law took effect.

Second.—Railroads doing an interstate business are not affected in the matter of capitalization, as are those entirely in the State, for the reason that they can still issue blanket mortgages covering the whole property irrespective of the Texas law.

Third.—The practice of the Commission, in allowing first cost of construction without depreciation, seems to favor unduly those roads which are not maintained properly, and there are several such in Texas.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

FREEZING AS AN AID TO EXCAVATION IN UNSTABLE MATERIAL.

Discussion.*

By Messrs. George E. Thomas, D. E. Moran, E. L. Abbott, T. Kennard Thompson and Werner Boecklin.

Mr. Thomas. George E. Thomas, M. Am. Soc. C. E. (by letter).—The writer has read this paper with much interest.

The ground pipes for the shaft at the Chapin Mines, Iron Mountain, Mich., were put down by the Chapin Mine Company, and have been described fully by D. E. Moran, M. Am. Soc. C. E., in a paper† before the School of Mines of Columbia College, New York City. This piping was finished in the summer of 1888, and, in August of that year, the writer was ordered by General William Sooy-Smith, President of the Poetsch, Sooy-Smith Company, to take charge of the work.

The design of the circulating piping and the whole installation of this plant was one of the writer's most interesting experiences. There were twenty-six stand-pipes, each with a specially designed head, the 8-in. cap being a special casting; also the connection above the 4-in. nipple; and every joint was soldered, to make certain that there would be no leakage. The 1½-in. intake pipe was extended down to 10 ins. above the bottom of the 8-in. stand-pipe, thus giving ample space for inflow.

* This discussion (of the paper by James H. Brace, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for January, 1904), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to April 23d, 1904, will be published subsequently.

† *School of Mines Quarterly*, Vol. XI, p. 237.

The refrigerating machine was started on November 19th, 1888. In twenty-four hours all the piping above ground and the circulating pumps were coated with frost. Previous to starting the freezing, the writer had put down a system of test pipes to afford information as to the distance the freezing had extended from the pipes. Mr. Thomas.

The explosives used were lime, black powder, and then dynamite. Large quantities were thrown out by each blast, the frozen material being so strong that the charge would split boulders instead of yielding before them.

The frozen sides of the shaft were also very firm. A depth of 40 ft. was excavated before any timbering was put in, and, at a depth of 80 ft. below the surface, a space of 7 ft. was left untimbered.

The leak which developed was caused by a boulder on the rock under one of the stand-pipes, and this proved to be a valuable experience. The temperature of the water coming into the shaft under this boulder was $+45^\circ$ Fahrenheit.

The adjustment of the circulating fluid, to harmonize the temperatures in the twenty-six stand-pipes, was one of the difficulties, and was overcome by the use of valves on the stand-pipes. There was not a variation of 0.1° in the temperature of any of the stand-pipes. Recording thermometers were used and gave good results.

Tests of the frozen material gave the following results:

Average of four tensile tests	= 431	lbs.	per	square	inch.
Maximum	= 491	"	"	"	"
Average of eight compression tests	= 575	"	"	"	"
Maximum	= 880	"	"	"	"

From August, 1888, when this work was started, the writer was alone, and working continuously, night and day. Mr. Moran came to assist on January 14th, 1889, and the work was finished early in the spring of that year. It was the writer's purpose to have written a paper on this subject, but other work prevented. He has a perfect history of the work and a number of photographs; also specimens of some of the finer material through which the shaft passed. One boulder weighed more than 17 tons.

This system of holding flowing material, such as silt, quicksand, or any form of unstable subsoil, is absolutely safe and reliable. Experience has demonstrated that refrigeration can safely be stopped for hours, or even days, after the frozen material has reached a consistency which is understood to be strong enough to withstand the required pressure. In comparison with the pneumatic process, the fact that there is no excessive pressure of air on the workmen is in its favor. The temperature at the bottom of the shaft at Iron Mountain was -25° Fahr., and was not any discomfort to the men when working. Such work, however, must be looked after carefully from start to finish, there being a law of compensation in all things.

Mr. Moran. D. E. MORAN, M. Am. Soc. C. E.—This paper is valuable in that it gives a *résumé* of the literature on the subject. In the opinion of the speaker, it is not an engineering paper on the subject of the freezing method; but is a *résumé* of the literature. It is very modest, and the author has made no claims for it beyond the fact that it is a condensation of what he could find printed on the subject. The speaker would like to see the subject treated on a more ambitious scale, taking up the theory, the practice and the results accomplished.

The entire subject seems to be of interest to every engineer. It is a new field, in America at least, and the problems presented are interesting and complicated, as they involve thermodynamics and statics. Civil, mechanical and mining engineers are all interested.

It is to be regretted that no one has thought it worth while to investigate the freezing process, and give answers to many of the questions, which, so far, seem to be unanswered. Some of these involve the higher mathematics, and the speaker has tried to solve them, but without success. It is desirable to have answers to certain questions which must arise wherever this process is to be used.

The only work done by the freezing method in America, as far as the speaker is aware, has been in charge of civil engineers, who are members of this Society, and probably most of them live in New York. The author refers to one or two articles written by members of this Society, and notes minor discrepancies therein. These discrepancies could have been explained by any one of the four men who were on the works. In the case of one alleged failure which he records, the author took the trouble to inquire and write letters to ascertain the difficulty. To the best of the speaker's knowledge and belief, the author did not ask any one of the four members of this Society who knew the real reasons why there was a failure or a partial failure of that work; but, he wrote elsewhere, and received a reply from a man who is not a civil engineer nor a member of this Society, the result being, that, while much of the information obtained was true, it was not an engineering answer to his question and it leaves much to be explained.

These criticisms are made because this subject is of great interest. They are made with all the more earnestness, because, while the author has not expressed his own opinions nor recited a single experience, nor advanced a single theory of his own, the speaker believes that he has ideas, understands the theory of the subject, and has had some experiences to record, and therefore would call on him for his own ideas, experiences and theories, rather than the best possible *résumé* of printed literature, which is available to all.

The author is to be thanked for having presented this paper, because it gives those who do not care to make search a chance to read an interesting paper and get the literature on the subject. But

it would have been better if the author had considered the problem Mr. Moran. from the standpoint of scientific engineering, and had given something more than a record of failures and successes in foreign countries, which failures or successes are not explained, and, as to which, he frankly confesses, some of the most important and interesting points can only be left to guesswork.

The speaker is a firm believer in the freezing process. The problems relate to the conductivity of materials, the specific heat of the materials to be frozen, the so-called latent heat of the water contained in the material, the rate of transmission of heat through material, and the effect of varying the temperature of the brine relatively to the temperature of the material involved.

It has been stated that the size of the ice machine required could be determined if the specific heat of the material to be frozen and the percentage of water contained in that material were known; but something must be added, because an ice machine has to do something beyond the zone of freezing. This represents a loss, and is one of the interesting questions to be settled before any calculation can be made as to the exact number of refrigerating units. These are only a few of the interesting questions of theory. There are also interesting questions of detail. One was touched upon in the paper, and related to the rupture of the pipes. At Iron Mountain, as described by Mr. Thomas, 10-in. pipes were sunk to the rock as pilot pipes, and 8-in. pipes, sealed at the bottom, were then inserted inside of the pilot pipes. The exterior 10-in. pipes were then withdrawn, leaving the 8-in. pipes in contact with the soil. The circulating pipe was then put inside the 8-in. pipe. There was no trouble with any of these pipes. At Wyoming the same process was followed, up to a certain point. The 10-in. pilot pipes were driven and smaller 8-in. pipes were placed inside of them, and then an attempt was made to withdraw the exterior pipe. In a number of cases it failed to come out, and so the circulating pipe was put in and the ice-machine started, leaving a steel pipe outside of the freezing pipe. Thus an annular space full of water was left between the two pipes. The first effect of the freezing was to freeze a thin film of ice on the exterior of the inner pipe. The inner pipe had sleeve couplings; the exterior pipe was flush at the joints, both inside and outside. The conductivity through the sleeve couplings was the same as the conductivity through the pipe and the thickness of ice was the same. The result was that the frozen wall of water extending out from the inner pipe first met the exterior pipe opposite these sleeve couplings, which were 20 ft. apart. The interesting experiment was thus had of a certain quantity of water freezing in a confined space. There were an interior and an exterior cylinder, and an annular space filled with the confined water. As soon as the water commenced to freeze it expanded. It might have

Mr. Moran. been expected that the expansion would burst the exterior cylinder; instead of that, it sheared the 8-in. pipe under the coupling so that when the pipe was withdrawn, long afterward, it came up in pieces, and it was seen that the thread had been sheared. It was a case of shear, not a case of tension; and the explanation is very simple.

That brings up another practical question relating to the ground pipes and the whole system. What becomes of the water? A case is mentioned in the paper where it was expected that this same experiment would be repeated, but on a larger scale, by freezing so as to confine the water. When the water freezes, what will happen? The speaker thinks there is nothing to be apprehended on that score. There might be a slight relative motion of the pipes in the ground, but as a block of ice under pressure in a glacier or elsewhere can be broken and will yet freeze again under pressure and at a suitable temperature, so the speaker believes a similar action would have taken place here, and therefore no trouble need have been apprehended from that source. If the rupture occurred, it could heal itself. That is one of the beauties of the freezing process.

The Wyoming shaft was finished by the pneumatic process. The story is told of an old professor who, when an experiment failed, said: "Gentlemen, this experiment has not failed. No experiment can fail." In that sense, the experiment at Wyoming did not fail. The material was frozen. The work was done by Mr. Sooysmith, and the speaker was there occasionally, but had nothing to do with carrying out the work or designing it, any more than he had at Iron Mountain, because he only went to the last-named work as assistant to Mr. Thomas; while, at Wyoming, he had no position except that of an observer. He can say that the Wyoming experiment taught him a great deal about the freezing process, including that little point about the pipes.

The freezing process has its limitations, as has every other system. That the ground was frozen, was proven when the pneumatic caisson was sunk, months afterward, because it was then necessary to go through the frozen ground. The speaker does not wish to describe the various things that happened at that Wyoming shaft. If Mr. Sooysmith had given it his personal attention, the speaker is sure that many things that did happen would not have happened. A freezing job is much like an experiment in a physical laboratory, in that it has to do with things that the ordinary superintendent does not understand. It is an engineering problem and a laboratory experiment on a large scale, and ought to be thus treated. In an article* on the Iron Mountain shaft, written by the speaker, from which some of the illustrations in the paper are reproduced, there is a calculation of the amount of freezing effect required to freeze the sand. In

* *School of Mines Quarterly*, Vol. XI.

speaking of freezing the sand, what is meant is the reduction of the temperature of the sand. and the amount of freezing effect required to freeze the water in the sand. At Iron Mountain the percentage of water was very low, only 17 per cent. The speaker was surprised to find how much of the freezing effect was required to freeze the water and how little was required to reduce the temperature of the sand, but the proportions are not remembered. A very small fraction of the total effect is required to reduce the temperature of the sand and water. Where there is rock the conditions are reversed, because there is a very small percentage of water in rock, and, therefore, it can be frozen very quickly, as has been shown to be the case in every freezing job. It was shown at Iron Mountain, where the pipes went down through a nest of boulders and the freezing effect had extended to a much greater distance from the pipes than in sand containing only 17% of water. Most of the experiments mentioned in the paper have been with inadequate ice machines. The modern ice machine is capable, if so desired, of giving a temperature of 40 or 50° below zero, and therefore gives very much greater results. It was stated in the paper that the pipes should be 4 ft. apart. One question which it would be desirable to consider is the basis on which the lay-out of the pipes must be designed with different degrees of temperature in the ice machine. At Iron Mountain, the temperatures were so little below freezing point that on many days but little progress was made. Mr. Moran.

It has been suggested that all ought to be interested in this question because practically all who have had any outside work know how much more expensive it is to excavate material in freezing than in warm weather. If, when a difficulty is met, that difficulty can be turned around and made to help the next time, the result is a success. That is what is to be done, some time, with freezing. It is to be made to help. It is expensive to excavate frozen material when frozen material is not wanted, but when it is desired to change a soft, wet, flowing material into something that is as hard as sandstone, a freezing machine should be used to put the material into the desired condition.

E. L. Abbott, Assoc. Am. Soc. C. E.—The speaker has examined the literature on the freezing process as applied to shaft work, and has studied its proposed application to tunneling in wet ground. The records of shaft work are not as complete as could be desired. Although information about the performance of refrigerating machinery is well known or may be easily obtained by test, exact data are required as to what happens below the ground line, in reference to the conductivity of ice and soils, and to what extent their conductivity is increased by a reduction of temperature. Mr. Abbott.

The results of laboratory tests on the conductivity of ice, as made by different physicists, vary greatly, and can be reconciled only by

Mr. Abbott. the supposition that they were made at different temperatures or under some other unknown conditions, which would indicate that the law of its conductivity is not well known.

While much practical information has been obtained at various shaft works, it can only be applied properly at other places when the conditions are similar, and where they are not similar it is usual to provide a liberal excess of refrigerating power to cover any unforeseen demand. The cost of refrigeration itself is generally but a small proportion of the total cost of the work.

Thanks are due the author for his compilation of many data which will assist in further investigations, and it is hoped that all who have opportunity for obtaining exact information on the subject will place it on record.

Mr. Thomson. T. Kennard Thomson, M. Am. Soc. C. E.—The author refers to the Harlem Speedway without giving any American references. The following is given for the sake of completing the record. Messrs. Steward and McDermott were the contractors for this work, and Mr. McDermott states that, after $8 000 had been expended for labor, in attempting to hold the water back by freezing, they were obliged to abandon this process as a failure for that particular locality. The Mr. Steward of this firm was the late Herbert Steward, Assoc. Am. Soc. C. E., and Mr. McDermott is Mr. Charles McDermott, now of the firm of McMullen and McDermott. He is now in Washington, D. C., and no doubt would be glad to give further information if desired.

It would seem to the speaker that the freezing process should only be attempted where the depths are too great for the use of compressed air, that is, where the water is more than 100 ft. deep, as the compressed-air method is cheaper, quicker and more reliable.

The author states that the freezing process has been proposed for the Pennsylvania Railroad's Hudson River tunnel. There the material to be penetrated is the finest kind of silt. If the freezing process were used for this work the tunnel lining, of course, would have to be placed against the frozen material, and when this material subsequently thawed out it would leave the tunnel floating practically in a jacket of water. The author refers to a case where soil water containing 3% of salt was frozen by doubling the capacity of the freezing apparatus, and, on the other hand, states that someone in the South has made an unsuccessful attempt to freeze a salt mine. It is an open question as to whether the Hudson River silt does not contain too much salt water to freeze readily.

In most cases quoted by the author it is stated that it was not considered safe to blast, and that the frozen material was chopped out with chisels, picks, etc. Frozen earth is the most difficult material the speaker has ever seen excavated. In removing the remains of an old Rocky Mountain snow slide on the Canadian Pacific

Railroad, blasting made almost no impression, as each blast simply blew out a small hole. Mr. Thomson.

It is to be hoped that the gentleman who controls the American patent rights of the Poetsch system will explain why so many of the attempts in this country have been failures, for failures often teach more than successes.

WERNER BOECKLIN, Assoc. M. Am. Soc. C. E.—Through the courtesy of the York Manufacturing Company, builders of refrigerating machinery, the speaker is able to present to the Society data, in the form of a proposal made to him, with a specification, covering a plant suitable for excavating purposes. Mr. Boecklin.

The specification, including the principal items, follows:

One 27 H.-P. steam engine of the horizontal type, with a 13½ x 12-in. cylinder, direct-connected to two gas pumps of vertical, single-acting type, with 9 x 12-in. cylinders. This machine is guaranteed to give a duty equal to the melting of 20 tons of ice in 24 hours.

One ammonia condenser, of the atmospheric type, consisting of two coils of 1¼-in. ammonia pipe, each coil to be about twenty-four pipes high and about 20 ft. long.

One ammonia receiver and an oil separator, the former being an air-tight tank to receive the ammonia as it is condensed.

One brine cooler, of double-pipe style, one pipe inside the other, consisting of two coils of 2-in. and 3-in. pipe.

One brine tank of sufficient capacity to hold about one-third of the total quantity of brine in circulation.

One brine pump large enough to force the brine through the system.

One 50 H.-P. horizontal tubular boiler, with a 60-ft. smoke stack 26 ins. in diameter.

One feed-water pump, 3 x 2 x 3 ins.

One feed-water heater of 50 H.-P. capacity.

The proposal includes all necessary piping and fittings, twenty-one freezing tubes, 8 ins. in diameter and 103 ft. long, with 1¼-in. circulating pipes and circulating and collector rings, a sufficient quantity of ammonia to charge the system and a sufficient quantity of chloride of calcium to make the needed brine of proper density.

The cost of the machinery and accessories, furnished and erected, exclusive of the placing of freezing pipes, will approximate $9 250. This figure will not be more than 5% out of the way.

The foundations for the engine and compressors, the boiler setting and the structure for housing the machinery, are items not included in the foregoing price.

Vol. XXX. MARCH, 1904. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THEORY OF THE SPHERICAL DOME WITH A HOMOGENEOUS SURFACE, AND OF THE FRAMED DOME; ALSO NOTES ON THE CONSTRUCTION OF MASONRY AND METAL DOMES.

Discussion.*

By Messrs. H. H. WADSWORTH and E. SCHMITT.

Mr. Wadsworth.

H. H. WADSWORTH, M. Am. Soc. C. E. (by letter).—In attempting to follow the reasoning and develop the author's formulas in that part of the paper relating to the spherical dome with a homogeneous surface, the writer, being unable to check some of the expressions there given, or even accept some of the hypotheses upon which they are based, has worked out the problem in a somewhat different manner, and presents the results in the hope that they will, at least, bring out further discussion.

The author's Equations 1 to 6, relating to the surface properties of a sphere, are correct and fundamental, though the reason for the development of Equation 6 is not apparent, as it merely expresses the condition previously assumed, *i. e.*, the weight of each square unit of the surface $= p$.

Let Fig. 42 represent a vertical section through the axis of a hemisphere, cut in two by a plane parallel with the equator at a

* Continued from February, 1903, *Proceedings*. See December, 1903, *Proceedings* for paper on this subject by E. Schmitt, Assoc. M. Am. Soc. C. E.

Mr. Wadsworth.

height, h, above it. Then the weight of the portion of the hemisphere above the cutting plane is $2 \pi R a p$, and of the portion below that plane it is $2 \pi R h p$.

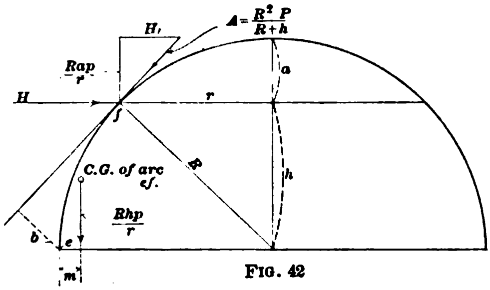


FIG. 42

Consider, now only, the spherical sector included between meridians at a distance apart of unity at their intersection with the cutting plane, and the weights of the respective portions will be:

$$\frac{2 \pi R a p}{2 \pi r} = \frac{R a p}{r}, \text{ and } \frac{2 \pi R h p}{2 \pi r} = \frac{R h p}{r}.$$

Before considering the sector of the whole hemisphere, take the upper portion only. The forces acting at the base of this are: The reaction of the support = the weight = $\frac{R a p}{r}$, the meridional tangential thrust, A, and a horizontal force, H.

From similar triangles, $A : \frac{R a p}{r} = R : r;$

or, $$A = \frac{R^2 a p}{r^2} = \frac{R^2 (R - h) p}{R^2 - h^2} = \frac{R^2 p}{R + h},$$

the value of A, as determined by the author.

Similarly, $H_1 : \frac{R a p}{r} = h : r;$

or, $$H_1 r = \frac{R a p h}{r} = \frac{R (R - h) h p}{\sqrt{R^2 - h^2}}.$$

But $H_1 r = B_1$ = the ring stress at this point (see the author's Equation 1); therefore, $B_1 = \frac{R (R - h) h p}{\sqrt{R^2 - h^2}}$.

In this equation, when $h = R$, or when $h = 0$, $B_1 = 0$. Equating the first derivative of this expression to zero gives the value of h, which makes B_1, maximum, $h_1 = 0.618\ R$, and, for this value of h, $B_1 = 0.3\ R^2 p$.

In Fig. 43 the abscissas to the curve marked $B_1 = -\frac{R (R - h) h p}{\sqrt{R^2 - h^2}}$ are the ring stresses (tension) at bases of domes in terms of $R^2 p$, for values of h (the height of the base above the equator) as ordinates.

Referring again to Fig. 42, and remembering that, since the ring stress at the equator is zero, as just determined, there will be no tendency for the dome to spread at this point, there will be, acting on the lower portion of the sector of the dome, the tangential meridional

Mr. Wadsworth.

thrust, $A = \dfrac{R^2 p}{R + h}$, the weight of the lower portion, itself $= \dfrac{R h p}{r}$, acting at the center of gravity of the arc, $e f$, and the force, H, acting in the cutting plane.

To maintain equilibrium, the algebraic sum of the moments of these forces must be zero.

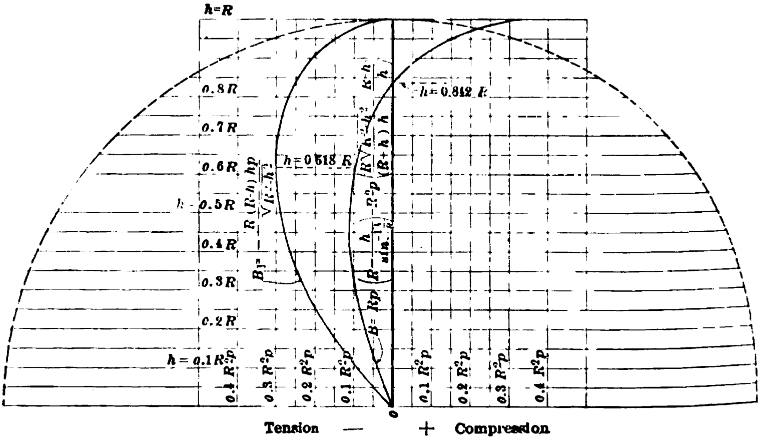


FIG. 43

Taking as the point of moments the equatorial base of the sector:

$$H h - \frac{R h p m}{r} + \frac{R^2 p b}{R + h} = 0,$$

or,

$$H = \frac{R p m}{r} - \frac{R^2 p b}{(R + h) h}.$$

Calling the ring stress at this point, B, then

$$B = H r = R p m - \frac{R^2 p b r}{(R + h) h}.$$

From Fig. 42 it is readily seen, or easily demonstrated, that $b = R - \sqrt{R^2 - h^2}$. m may be determined by an application of the theorem that the area of a surface of revolution is equal to the length of the generating curve multiplied by the distance described by the center of gravity of the curve.

In this case, the length of the arc $= R \sin.^{-1} \dfrac{h}{R}$, and the distance traveled by the center of gravity is $2 \pi (R - m)$. The area of the zone has been found to be $2 \pi R h$;

therefore,

$$2 \pi (R - m) R \sin.^{-1} \frac{h}{R} = 2 \pi R h;$$

$$R - m = \frac{h}{\sin.^{-1} \dfrac{h}{R}}, \text{ and } m = R - \frac{h}{\sin.^{-1} \dfrac{h}{R}}.$$

Mr. Wadsworth.

Then, in the equation, $$B = R\,p\,m - \frac{R^2\,p\,b\,r}{(R+h)\,h}$$

substitute for m, its value, $R - \dfrac{h}{\sin.^{-1}\dfrac{h}{R}}$;

substitute for b, its value, $R - \sqrt{R^2 - h^2}$;

and substitute for r, its value, $\sqrt{R^2 - h^2}$;

and the result is

$$B = R\,p\left(R - \frac{h}{\sin.^{-1}\dfrac{h}{R}}\right) - R^2\,p\left[\frac{R\sqrt{R^2-h^2}}{(R+h)\,h} - \frac{R-h}{h}\right].$$

The curve represented by this formula is also shown in Fig. 43, the ring stress at any parallel, a height, h, above the equator, is given by the abscissa to the curve at that point.

It will be noticed that this curve crosses the zero line of stress at a height above the equator of $h = 0.842\ R$, instead of at a height of $0.618\ R$, as determined by the author; and it will be noticed, also, that this latter height, as already pointed out, is the position of the base of a dome, less than hemispherical, which gives the maximum base ring stress.

The curve of ring stresses in hemispherical domes shows the maximum tension to be at $h = 0.5\ R$, approximately, and that the tension at this point is $0.11\ R^2\,p$.

For a practical application to a masonry dome, let t = the thickness of the masonry, in feet, also the unit of surface measurement.

Let w = the weight of the masonry per cubic foot;

then $$p = w\,t^3.$$

Let R_1 = the radius of the dome, in feet (R being the radius expressed in the units of which p was the weight of a square unit),

then $$R = \frac{R_1}{t}.$$

Then, in the expression, $0.11\ R^2\ p$, substitute for R and p the values just found, and the result is

$$\frac{0.11\ R^2_1\ w\ t^3}{t^2} = 0.11\ R^2_1\ w\ t.$$

If the tensile strength of the stone be K pounds per square inch, or $144\ K$ pounds per square foot, the strength of a ring having a width and thickness of t will be $144\ K\,t^2$;

then $$0.11\ R^2_1\ w\ t = 144\ K\,t^2.$$

Solving for K, gives $$K = \frac{0.11\ R^2_1\ w}{144\ t}.$$

According to Table No. 3, the dimensions of the dome of the Santa Sophia Cathedral at Constantinople are $R_1 = \dfrac{115}{2} = 57.5$ ft., and $t =$

Mr. Wadsworth. $2\frac{1}{4}$ ft. (this is the thickness at $h = \frac{R}{2}$), assuming that the thickness varies uniformly from 2 ft. at the top to $2\frac{1}{2}$ ft. at the base;

then $$K = \frac{0.11 \times (57.5)^2 \times 160}{144 \times 2\frac{1}{4}} = 162 \text{ lbs. per square}$$ inch, tension in the masonry ring. (The weight of the stone per cubic foot is assumed at 160 lbs. $= w$.)

Of course, the fact that this dome is built with a varying thickness from base to top, and that it is buttressed, renders the formulas herein derived not exactly applicable; but it would seem that the builder did not depart widely from good practice, as far as the strength of the stone itself is concerned.

Further, the fact that, at the base, the ring stress is zero, makes the openings, of which the author states there are forty, unobjectionable.

Mr. Schmitt. E. SCHMITT, Assoc. M. Am. Soc. C. E. (by letter).—Attention is called to the fact that Rankine, Schwedler and Dr. Robison are mentioned in the paper as those who solved the problem of the stresses in a spherical dome "a long time ago."

As to the use of trigonometrical functions in practical working formulas, the writer will give two examples:

1.—The ring stress in a hemispherical dome, at any altitude, is:

By Schwedler: $$B = p\,R\left(\frac{1 - \cos.\ \alpha - \cos.^2\ \alpha}{1 + \cos.\ \alpha}\right)$$

In the paper: $$B = -\frac{R^2}{R + h}\,p + p\,h \qquad (15)$$

Wherein $\alpha =$ the angle from the vertex, and $h =$ the elevation of the joint in question above the equator.

2.—The thrust, by a single load, on a two-hinged circular arch, is given in the following forms:*

By Winkler:

$$H = W \frac{\sin.^2\alpha - \sin.^2\beta + 2\cos.\alpha\,(\cos.\ \beta - \cos.\ \alpha) - 2\cos.\ \alpha\,(\alpha \sin.\alpha - \beta \sin.\beta)}{2\,[\alpha - 3\sin.\ \alpha \cos.\alpha + 2\,\alpha \cos.^2\ \alpha]};$$

By Engesser: $$H = W\frac{a\,R\,(l - a) - 2\,h\,(c - c_1)\,a - h\,l\,c_1 + 2\,R\,h\,d}{2\,R^2\,c + 4\,h^2\,c - 3\,h\,R\,l}.$$

---

* Wherein, in Winkler's formula:
- $W =$ the single load;
- $\alpha =$ the angular measure of half of the arch;
- $\beta =$ the angular measure of the load point from the vertex.

In Engesser's formula (origin in one of the hinges);
- $l =$ span;
- $h =$ radius, minus rise of arch;
- $R =$ radius;
- $a =$ abscissa of the load point;
- $d =$ ordinate of the load point;
- $c =$ half the length of the arc;
- $c_1 =$ the length of the arc, from the origin to the load point.

Professor Church has called attention to the following paragraph in relation to Case II, on page 1104:* Mr. Schmitt.

"If B, the resisting or balancing force, as it were, is assumed to be reckoned per unit length of circumference, and for one unit of length along the meridian," etc.

When writing this "conclusion" the writer had in mind the co-related behavior of the shearing stresses on the four faces of an element, considered free, and which are all, and are always, of the same intensity per unit of area.

This theorem is demonstrated in all handbooks on applied mechanics, and the writer sees no reason why, in this instance, it should fail to work.

All who are interested are referred to Professor Church's "Mechanics of Engineering,"† where, under "Shearing Stresses," will be found the theorem as stated above.

Now, in this case, the "element" is a spherical square, situated at the base of the dome, and of which each side measures one unit of length.

If, now, the shearing stresses, along the meridional sides of this element, are caused by the thrust, A (acting per unit of length of the circumference), is it true, or untrue, that the ring stress, B, per unit of length along the meridian, is of the same intensity as the stress, A, the unit of area being common to both?

If this reasoning is "loose and elusive," Professor Church may, possibly, remove some of the obscurity as to the meaning and applicability of this theorem, as the qualifications as to clearness would attach thereto, if it cannot be made use of, in this case, also.

The following theorem is submitted in proof of the statement that, at the base of any dome, the tensile ring stresses, and also the shearing stresses, are all of the same intensity, and equal to the known meridional compressive thrust, A.

Theorem.—When, upon two opposite sides of a rectangular element (whereof each side measures one unit of length), there acts an "applied" compressive force, of a magnitude $= A$, and "induces" upon the other two sides a tensile stress, B, then this induced stress is of the same magnitude as the applied force. The shearing stresses along the four sides of this element must also be of the same intensity.

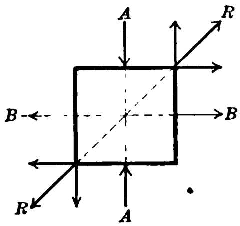


FIG. 44

In Fig. 44, considering equilibrium in a diagonal direction, the resultants of the compressive and tensile stresses (of two adjacent sides), must pass through opposite corners of

* *Proceedings*, Am. Soc. C. E. for December, 1903.

† Edition of 1888, paragraph 209, page 228.

Mr. Schmitt. the element, and have an inclination of 45° to any of the sides, for, if this should not take place, the shearing stress components of the resultants would not be of equal magnitude, which, however, for equilibrium, they must be. It also follows that all the stresses have the same intensity.

As to the stresses in spherical and conical domes, given in the second part of the paper, and there derived from the general case of the pyramoidal dome, it will be necessary to prove that the formulas for this general case are defective, before making exceptions as to the results obtained from them for conical domes.

Professor Church finds, for the compressive ring stress, "at any altitude," in a conical dome:

$$B = \frac{r^2}{a} p \ldots\ldots\ldots\ldots\ldots\ldots\ldots (71a)$$

This is wrong. This expression represents simply the compressive ring stress at the top of a truncated dome. The writer would suggest that, in this case, the tensile ring stress at the base of a given cone be found first, and then the compressive ring stress at the top of a truncated cone, both in reference to a common radius, and then add the results.

Professor Church finds the ring stress in all conical domes, whether complete, truncated, with or without a lantern load, and at any angle of inclination, to be always a circumferential compressive stress, and equal to

$$B = + \frac{r^2}{a} p \ldots\ldots\ldots\ldots\ldots\ldots\ldots (71a)$$

Assuming a self-contained conical dome, standing upon an open-jointed, circular, stone base (see Fig. 45), the question arises: What must be the magnitude of the tensional resistance in the bottom course of this cone? There is no doubt that this stress is a tensile one; otherwise, the dome would spread, and would not be self-contained. The next question is: What induces this tensional stress? Is it the inclined reaction, A, or is it due to some other applied force, and what is that force? If A, as the writer claims, is this force, and induces tension, then the ring stress, B, will increase as A increases, say, for instance, through the action of a lantern load.

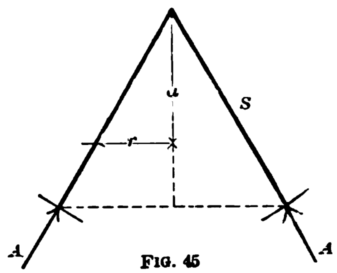


FIG. 45

Continuing, Professor Church writes:

"But, at 90°, the cone becomes a cylinder, of infinite height, in which case, of course, there is no hoop stress of either kind in the horizontal course; but, from Equation 71, this hoop stress, for an angle of 90°, would be tensile, and infinite in value."

This can be admitted as the most likely thing to occur, since the value of A also becomes infinite. Not much of the cone would remain in that instance, at least not much of the bottom course. But, assuming, also, with Professor Church, that a truncated cone, just one unit of measure in height, and with an inclination of 90°, is to be dealt with, then, evidently, Mr. Schmitt.

$$B = + r^2 p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (85)$$

That is, this cylinder is subjected to a compressive ring stress, increasing with the square of its radius. This result, therefore, would seem to be manifestly erroneous, as far as Professor Church is concerned, because, as he writes, there are no ring stresses in cylinders standing on end. Yet this contradictory result is obtained by following Professor Church's reasoning, and by the use of the formula established by him.

Professor Church seems to be given somewhat to hair-splitting, when he objects to having apparently combined the action of stresses not located in the same parallel of altitude, but instead just above and just below the same, respectively, and as was done in the paper in the case of the ring stresses at any altitude in a spherical dome, under Case III. With a little imagination it is to be perceived that when it is wished to discover the combined action of these stresses for a mere point, then the courses in which these stresses take place, and are to be combined, coincide, that is, overlap one another.

Professor Church cites Rankine's "Applied Mechanics" in corroboration of the correctness of the results obtained by him for conical domes.

Referring to Equation 15 for the ring stress at any altitude in a spherical dome, namely:

$$B = -\frac{R^2}{R + h} p + p\, h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

and applying the same to the parallel of altitude, $h = 0.618\ R$, that is, at the joint of rupture, then the ring stress, B, is found to be $= 0$. However, Rankine * writes:

"The angle of rupture, for which $p_z = (B) = 0$, is

$$i_0 \operatorname{arc} \cdot \cos. \frac{\sqrt{5} - 1}{2} = 51° \, 49' ; \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

and from this angle we obtain, for the horizontal thrust of the dome, per unit of periphery at the joint of rupture,

$p_y = 0.382\, p\, r$;

and for the tension on a hoop to resist that thrust, ...(7)"

$P_y = 0.3\, p\, r^2$.

The writer believes that Professor Rankine is here in error.

As mentioned, there is no ring stress at the (misnamed) joint of rupture; consequently no hoop is needed there. The compressive effect of the (overhanging) top course of the lower part, offsets, by an

* "A Manual of Applied Mechanics," p. 267.

Mr. Schmitt. equal amount, the tensile, spreading, effect produced in the bottom course of the upper part.

The facts in the case are these: If the dome extended from the crown no further than to the joint of rupture, and were to form a self-contained shell, then a hoop would be needed around the base, to accomplish this end. The hoop would have to resist a tensile stress of $B = 0.618\ R\ p$, and not, as Rankine has it, of $0.3\ R^2\ p$.

If, however, the dome is a complete half sphere, and, also, is assumed to be a self-contained shell, then the lower part (below the joint of rupture) must be designed so as to conform in strength to the requirements of Equation 15, or be reinforced by hoops.

If the tension zone (the lower part) of the dome is now constructed as stated, it will resist effectively all the meridional downward pressures brought to bear upon it from above, and this without the assistance of a hoop at the joint of rupture.

Having thus shown that Rankine has evidently made a statement, relative to the stresses in spherical domes, not borne out by the facts, it is possible, therefore, that his deductions for the ring stresses in conical domes, also, are erroneous.

To answer Mr. Wadsworth's discussion properly, it is necessary to have a clear conception of the sense and direction, and of the magnitude of the external forces, acting, in the one case, in the top course of the lower part, and, in the other case, at the base of the upper part.

The two cases are radically different, as regards the question of determining resultants and components.

In Fig. 46, which represents the external forces acting at the top of an open dome, the forces, H_0 and A, are the components of the initial force (weight) p.

Therefore, when these components, H and A, are considered in their action upon the top course, they at once represent the effect of p, that is, p drops out of the computation in this case.

Now, since the inclined meridional component force, A, is taken up, directly, by the next lower course, the component, H, is the only force to be considered as having an effect upon the top course, as in accordance with Case I.

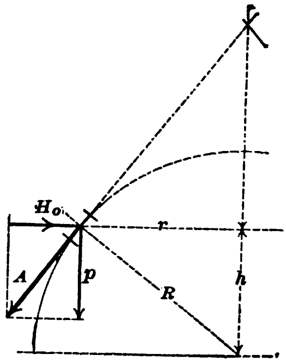


FIG. 46

In Fig. 47, which represents the external forces acting at the base of the upper part of a dome, H and W are the components, and A is the resultant of these two.

In this case, therefore, it is necessary to enter into the computations, either the two forces, H and W, together, or else only the inclined meridional upward reaction, A. Mr. Wadsworth neglected

Mr. Schmitt.

to analyze the external forces in this manner in both instances, and did not consider that, in an open dome, the top course forms an equilibrated ring, in compression; further, that the weight and the stresses in the lower courses have no effect whatever upon any of the upper courses, except in the case of two superimposed (*i. e.* overlapping) courses, as under Case III.

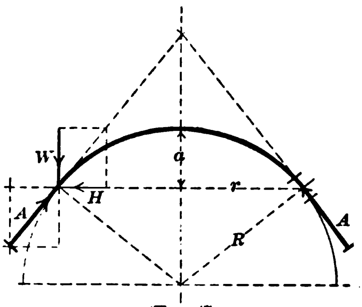


FIG. 47

On the other hand, all lower courses are affected by the upper ones, that is, by the inclined meridional thrust, A, due to the weight of these courses.

In the lower supporting courses, and below the joint of rupture, tensile ring stresses are created thereby, and, in the case of a hemispherical dome, a tensile stress at the base is produced equal to

$$-R\,p \qquad (17)$$

Mr. Wadsworth has treated the lower part of a spherical dome as if it were a part of a cylindrical vault. The stresses in a dome have nothing in common with the stresses in an arch. It is a mistake to assume the whole of the lower part of the dome to have an effect upon the bottom course of the upper part.

The writer considers all the formulas established for the stresses in domes in the paper to be correct.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

JAMES PETER BOGART,* M. Am. Soc. C. E.

DIED DECEMBER 24TH, 1903.

James Peter Bogart, son of John and Henrietta Candee Bogart, was born at New Haven, Connecticut, on February 28th, 1852.

His early education was obtained in the public schools of New Haven, and he completed his course in the Hillhouse High School in 1869. He then entered the Sheffield Scientific School of Yale University, taking the course in civil engineering, and receiving his degree in 1872.

After graduation he was employed by Mr. H. G. Scofield, of Bridgeport, Connecticut, in general engineering work for about three years. In 1875 he entered the service of the United States Coast and Geodetic Survey, and was employed for three years, under R. M. Bache, in charge of a plane-table survey of the region in the vicinity of New Haven. Upon the completion of this work, he returned to Bridgeport and again entered the employ of Mr. Scofield, where he remained for about three years, during which time a detailed survey and map of the entire city was made from which an official atlas of the city was printed.

In 1881, the Legislature of Connecticut appointed a commission to promote the new and rapidly increasing interests of the deep-water oyster-growing industry. This commission appointed Mr. Bogart to be its Engineer, a position which he filled for about eleven years. During this time he executed a very careful triangulation of the Connecticut shore of Long Island Sound from the Connecticut River to Greenwich, a length of about seventy miles; established an extensive system of signals and ranges for locating the boundaries of the oyster beds in the Sound, and surveyed and mapped 70 000 acres of oyster farms.

This was employment for which he was peculiarly well fitted. His natural thoroughness, together with the training he received in the service of the Coast Survey, made him exceedingly precise and painstaking in his work. Where such important and diverse interests as those relating to the establishment of boundaries between these oyster farms were concerned, Mr. Bogart's characteristic honesty, industry and carefulness were of special value.

---

* Memoir prepared by Charles A. Ferry, M. Am. Soc. C. E.

During this period he also served as Engineer to the commission which, acting with a similar commission from the State of Rhode Island, established and defined the boundary line, below high-water mark, between these two States.

In 1892 he bought out the business of Mr. Frank Bruen, who for several years had conducted an engineering office in New Haven, and took into partnership Mr. A. William Sperry, who had previously been Mr. Bruen's assistant. This partnership continued until 1899, when Mr. Sperry withdrew and Mr. Bogart subsequently conducted the office alone.

His familiarity with the boundaries of the oyster beds, the thoroughness with which he performed his work, and his strict integrity, created great demand for his services in cases of dispute, between owners of adjoining oyster beds, in settling the correct location of boundary lines.

His work lay principally along the line of surveying, rather than engineering, and was always executed with great care and with a high degree of precision.

Mr. Bogart was pre-eminently a man of domestic habits, and found his chief pleasure in his home and the society of his family.

Mr. Scofield, in whose employ Mr. Bogart spent so many years of his professional life, thus writes:

"He was a painstaking, conscientious workman, no detail being too small to receive careful investigation. Mr. Bogart, though naturally of a retiring disposition, was a courteous gentleman, a genial companion and a loyal friend; and, while fully recognizing the rights of others, was thoroughly insistent on the maintenance of his own."

He was a member of the Connecticut Society of Civil Engineers and also of the New Haven Chamber of Commerce.

In 1888 he married Miss Helen Day, daughter of Warren H. and Eliza H. Day, of Bridgeport, who, with two daughters, aged, respectively, fourteen and six years, survive him.

Mr. Bogart was elected a Junior of the American Society of Civil Engineers on January 4th, 1882; and became a Member on July 3d, 1895.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

CONTENTS.

PLATE.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

ON SEDIMENTATION.

By Allen Hazen, M. Am. Soc. C. E.

To be Presented June 1st, 1904.

Since Sedden published his paper on "Cleaning Water by Settlement,"* there has been but little published discussion on the theory of this subject, but the practice of building and operating sedimentation basins has advanced materially. For example, it has been found in St. Louis that continuous operation, that is to say, a continuous flow of water into, through and out of the basin, gives quite as good results as the intermittent operation which was studied by Sedden, and the new arrangement allows the effluent to be delivered at a higher level, the economical advantage of which is evident. The use of baffles has also been learned, and it has been shown clearly that a well-baffled basin will do as much work as a much larger basin without baffles. A discussion of the subject from a theoretical standpoint, in view of these developments, may lead to a better understanding of it, to the collection of better data, and to improvements in design.

The processes which take place in sedimentation are extremely complex; to discuss them at once in their entirety seems hopeless. First, conditions much simpler than those which actually exist must

* *Journal of the Association of Engineering Societies*, 1889, p. 477.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

be assumed, and from these simple assumptions the more complex conditions can be approached.

General Assumptions.

Let it be assumed, first, that whenever a particle of suspended matter hits the bottom it remains where it strikes and is never carried forward on the bottom or picked up again; second, that all the sediment in the water is of the same hydraulic value; that is to say, that every particle settles through water at the same rate as every other particle.

Let t = the time required for a particle of sediment to fall from the surface to the bottom of the water in the basin, the water meanwhile being absolutely still;

a = the time of sedimentation in case the action is intermittent; and, in case of continuous operation, let a be the quotient obtained by dividing the capacity of the basin by the quantity of water entering or leaving it during each unit of time;

n = the number of basins, in case several basins are used successively;

x = the proportion of sediment remaining at the end of the process, the amount at the beginning being taken as unity.

Proposition 1.—Assume a basin full of water containing sediment, the water being absolutely at rest and so remaining.

Under these conditions, each particle of sediment will settle toward the bottom at its determined velocity. At the end of a certain period all the particles will have been removed from a top layer of water, which layer will be as thick as the distance that a particle will fall in the elapsed interval, while an amount of sediment equal to that originally contained in the cleared layer at the top will have been deposited upon the bottom. The time required for the removal of all the sediment will be the time required for a particle to settle from top to bottom, or t; and the proportion removed in a shorter period, a, will be $\frac{a}{t}$; and the proportion remaining will be one, less this amount. We then have:

$$x = 1 - \frac{a}{t} \qquad (1)$$

The values of x for various values of $\frac{a}{t}$ are plotted in Fig. 1 as Line A.

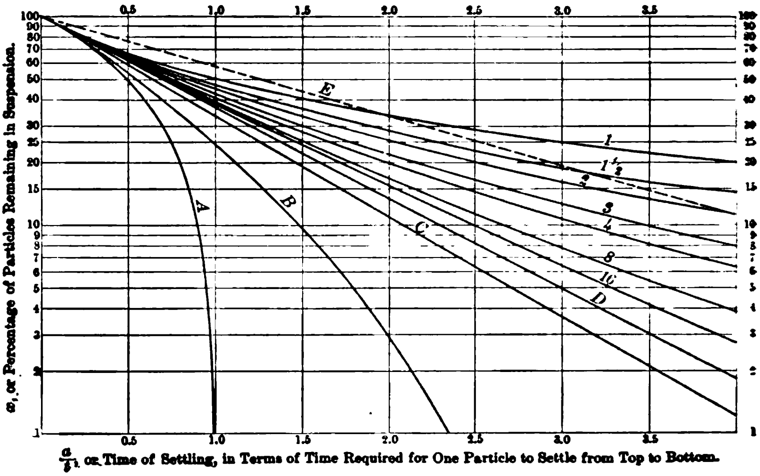


FIG. 1.

In an actual settling basin the water is mixed more or less from top to bottom in the process, with the result that the sediment does not go down in the manner indicated by the assumption. The most important causes of motion are:

1.—The kinetic energy of the water as it enters, which, according to Sedden, is still capable of producing vortex motion after long periods, but which can be much reduced by controlling the water at the entrance so that it has only a very low velocity.

2.—The action of wind (acting in open, but not in covered, basins).

3.—Changes in temperature, which, even though slight, change the specific gravity of the water and produce currents in it.

A development of this proposition, and of the motions of the water, and the resultant mixings, is given in much detail in Sedden's paper.

Proposition 2.—Assume a basin containing water, with sediment as before; and assume that the water is kept mixed during the process of sedimentation to such an extent that the density of the sediment in all parts of the basin is always the same.

In a period of time, $d\,a$, the movement of water in mixing will be inappreciable. The proportion of sediment remaining after the expi-

ation of this period, according to Equation 1, will be $1 - \frac{d\,a}{t}$. Now, he sediment remaining after each subsequent interval, $d\,a$, will be the ame proportion of the amount present at the beginning of that interval as it was after the first interval. If, therefore, the proportion remaining after the first interval be multiplied by itself as many times s there are intervals, the amount left at the end of the period will be btained. The number of intervals will be $\frac{a}{d\,a}$, and we have

$$x = \left(1 - \frac{d\,a}{t}\right)^{\frac{a}{d\,a}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

To solve this, make $a = t$ and develop by the binomial theorem. It is then found that when $\frac{a}{t} = 1$, $x = 0.367878$. The values of x for other values of $\frac{a}{t}$ can be computed from this value by the use of logarithms, and these values are plotted in Fig. 1 as Line D.

The mixing assumed is obviously more complete than could exist. To maintain it would require infinite velocities. This condition is impossible, but as it represents one limit of a series, the intermediate terms of which do exist, a consideration of the conditions at the limit aids in the study of actual conditions. If the degree of mixing were less than assumed, the rate of deposition would be more rapid.

Modification of Proposition 2.—Assume that the mixing is such as to keep the density of the sediment in all parts of the lower seven-tenths of the depth of the basin the same, and that in the upper three-tenths of the depth the density of the whole decreases gradually from the full amount to nothing at the surface, the average density being nine-tenths of the density at the bottom.

This assumption agrees reasonably well with the observed densities of sediment at different depths in sedimentation basins. The amount of sediment in the whole basin will then be nine-tenths of what it would be if the density of the sediment at the bottom were maintained to the top, and the density in the bottom layer, from which sedimentation is taking place, will be $\frac{1}{0.9}$ of what it would be if the mixing were complete. The amount of deposit in any interval of time depends upon the bottom density, and would thus be one-ninth faster than it would be with absolutely complete mixing. A given value of x will

then be obtained in nine-tenths of the time that would be required for an equal value of x on the assumption of complete mixing.

This should be corrected slightly, because at the outset the sediment at the top will be as dense as below. The advantage only occurs after the water at the top has commenced to clear. It can be assumed that the time required for this initial cleaning at the top will be 0.1 t, and the gain will amount to 10% of all subsequent time. The equation of this new line is not computed, but is easily laid off graphically, and it is shown on Fig. 1 as Line *C*.

This line may be taken as representing the rate of deposition of sediment on the intermittent system. That is to say, when a basin is filled, allowed to stand until settled, and then drawn off. To compare this line with the results obtained with basins operated with a continuous flow through them, it is necessary to take into account the reserve basin capacity required for the intermittent system of operation. That is to say, the period taken for computation covers only the time that sedimentation is actually taking place. Before this commences, the basin must be filled; and, after it is over, the basin must be emptied. These operations take time. The amount of time out of service will be dependent upon the conditions of service; and, assuming it to be equal to the time of actual use, then twice as much basin capacity will be required, to produce a given result, as is indicated by this line. A line drawn upon this basis on Fig. 1 is marked *E*.

Proposition 3.—Assume a sedimentation basin operated on the continuous plan; that is to say, with water constantly entering at one place and leaving at another. Assume that the water in the basin is kept constantly and perfectly mixed, so that the density of sediment in all parts of it is the same.

As the water in the basin is always perfectly mixed, the density of sediment in the mixture is the same as it is in the effluent, namely, x. In a period, $d\,a$, the proportion of sediment deposited will be $\frac{d\,a}{t}$, and the amount deposited will be $x\left(\frac{d\,a}{t}\right)$. The amount of water entering will be $\frac{d\,a}{a}$, and, as the amount of sediment in this water is unity, the amount of sediment will be $\frac{d\,a}{a}$. The amount of sediment carried by the effluent will be x multiplied by this amount,

or $x\left(\frac{d\,a}{a}\right)$. The amount of sediment deposited must be the difference between that in the water entering and leaving the basin, and we have

$$\frac{x\,d\,a}{t}=\frac{d\,a}{a}-\frac{x\,d\,a}{a}.$$

Solving, we obtain,

$$x=\frac{1}{1+\frac{a}{t}} \quad \text{.......................}(3)$$

The values of x computed from this equation are shown in Fig. 1 as Line *1*.

First Modification of Proposition 3.—Assume that the water near the surface carries less sediment than the water in the lower part of the basin, owing to the fact that the mixing is not complete.

Sedimentation will take place more rapidly than is indicated by the equation, and the correction to be made can be computed by the method used under Proposition 2, and, on the same assumptions, it will amount to 10 per cent.

Second Modification of Proposition 3.—Assume that the entering water has a velocity so great as to prevent the deposition of sediment over a certain area.

As far as this is the case, the rate of deposition for the whole basin will be less than computed, in the proportion that the area over which the excessive velocity acts bears to the total area of the basin.

The two corrections suggested by the modifications to Proposition 3 act in opposite ways and tend to balance each other.

Proposition 4.—Assume two basins so arranged that the effluent from one enters the second, all the other conditions remaining as assumed under Proposition 3.

The time period for the first basin becomes $\frac{a}{2}$. The proportion of sediment remaining after passing the first basin will then be, by Equation 3, $\frac{1}{1-\frac{a}{2\,t}}$, and the proportion of this amount remaining after passing the second basin will be the same as it was in the first basin, the amount contained in the water leaving the second basin will then be the square of the proportion in the water leaving the first basin, and we have:

$$x=\left(\frac{1}{1+\frac{a}{2\,t}}\right)^2 \quad \text{.........................}(4)$$

The values of x computed by this equation are shown in Fig. 1 as Line *2*.

Proposition 5.—Assume a series of n *basins, the water flowing from each to the next, all other conditions remaining the same.*

The computation will then be the same as under Proposition 4, and we have,

$$x = \left(\frac{1}{1 + \frac{a}{n\,t}}\right)^n \quad \text{.......................} (5)$$

The values of x for three basins are shown in Fig. 1 as Line *3*; for four basins as Line *4*; for eight basins, as Line *8*; and for 16 basins as Line *16*.

If a single basin is very long, and the flow through it is very regular, it is obvious that the ends will have a tendency to act separately; or, in other words, to act as if it were two basins. The formula is general, and we can make $n = 1.5$ for use with such single basins. This line is plotted in Fig. 1 as Line $1\frac{1}{2}$.

Proposition 6.—Assume an infinite number of basins, that is to say, absolutely complete baffling and continuous forward movement of the water at all points, mixing from top to bottom, but with no mixing backward and forward.

The value of n, in Equation 5, becomes infinity, and we have

$$x = \left(\frac{1}{1 + \frac{a}{n\,t}}\right)^n = \left(1 - \frac{a}{n\,t}\right)^n \quad \text{................} (6)$$

This equation gives the same values of x as Equation 2, and these are represented by Line *D*. In other words, theoretically, a sedimentation basin operated on the continuous system with absolutely complete baffling, would give the same results as a basin on the intermittent system kept absolutely mixed from top to bottom.

Proposition 7.—Assume that there are areas, in corners, etc., where the water remains away from the current passing through the basin, and with little or no exchange with it.

If these areas are entirely out of circulation, they might as well not be there, and sedimentation will take place in the remaining area as if they did not exist. If there is some circulation between these nearly dead areas and the current, they will be of service. If the circulation is sufficient to keep the density of the sediment in the water in these areas up to that in the water in the current at the point where

the current touches the nearly dead area, then sedimentation will be taking place in these areas as actively as elsewhere and no deduction should be made for them. If the circulation is less active than this, the water will contain less sediment than in the current, but still some proportion of it, and the efficiency of the spaces will be in direct proportion to the density of the sediment in the water in them.

For instance, if the whole area of such nearly dead space is 20% of the area of the basin, and if the water in them contains half as much sediment as the water in the current, then 20% of the area is doing half duty; and the whole amount of work done will be that which would be done by a basin nine-tenths as large, and with no such areas.

Proposition 8.—Assume that the water in a basin has, at the bottom, everywhere, or in some places, such a velocity that it will keep the particles moving and hold them in suspension, and will prevent them from being deposited.

If a bottom velocity in a sedimentation basin is such as to prevent the deposition of particles, the work of the basin will be less complete than it would otherwise be. It would seem that deposition would be limited to particles so large as to be capable of being deposited at the existing bottom velocity and that the work of the basin would be limited to the removal of particles larger than this size. This, however, is probably not quite correct, because the velocities in a basin are variable, and even though the average bottom velocities were such as to prevent the deposition of particles of a certain size, there would be areas in the basin where the velocities were below the average, and where these particles might be deposited. The results to be accomplished would thus be represented by the action of a smaller basin, the area of which would be that part of the area of the actual basin in which the bottom velocities were low enough to allow the deposition of particles. The problem is a complicated one, but it seems very clear that bottom velocities should be avoided at all points which would interfere with the deposition of any particles which would otherwise be removed.

If a particle rested upon a smooth bottom and wholly above it, a bottom velocity equal to the velocity at which the particle would settle through still water would exert a pressure on it equal to the weight of the particle, and this would certainly suffice to move it.

On a rough bottom, that is to say, a bottom already covered with particles, many of which might be larger than the particle under consideration, it would seem likely that only a part of the surface of the particle would be exposed, while the resistance to moving would be much greater. Still, it would seem that if the velocity was much in excess of the velocity at which the particle would settle through still water, it would move it. Certainly, if it were moving with the water, it would prevent it from being deposited.

It thus seems a fair conclusion that a bottom velocity approximately equal to the velocity at which a particle would settle through still water would prevent deposition. This statement refers to the velocity within a distance of the bottom measured by the diameter of the particle. That is to say, within 0.1 mm., and even within 0.01 mm. of the bottom and less. Now, nothing whatever is known about the velocities so very close to the bottom. The bottom velocities which can be measured are much farther from the actual bottom. It may be that, with the moderate velocities usually present in sedimentation basins, the action is that of water below the critical velocity, and that the water is attached to the bottom, and has no bottom velocity, and that velocities only commence to exist as the bottom is left, and only become appreciable at distances greater than the diameters of the particles under consideration.

The ordinary mean horizontal velocities in a number of sedimentation basins, to be mentioned later, range from 1 to 8 mm. per second. These velocities are so low that it seems certain that the velocities caused by wind, and perhaps also by temperature changes, will exceed them. As far as this is the case, the controlling velocity would be due to other causes than the general forward movement of the water, and the velocity of this movement becomes of secondary importance.

If the velocities were much greater, the problem would become simpler. It could then be assumed that the bottom velocity was some proportion of the mean velocity, and that the ratio between them was represented by an approximately constant factor, f. Then, the velocity at which particles settle through still water could be taken as, approximately at least, the limiting velocity at which particles would deposit; and, multiplying this by f, would give the mean velocity of the greatest current at which deposition would not be prevented. As-

suming thus a mean velocity, f times as great as the velocity at which the particle settles, the particle would have time to settle from top to bottom of a basin in making a forward movement equal to f times the depth of the basin.

Now, to secure a satisfactory removal of particles with a well-designed sedimentation basin the value of $\frac{a}{t}$ must reach a value which may be taken as approximately 1.5. That is to say, the horizontal course would require to be 1.5 times as long as that course through which water would flow while a particle was settling from top to bottom. This gives the limiting ratio of the longest course which the water is obliged to follow in passing a basin to the depth of the basin at about 1.5 f. To make the water follow a longer course than this would prevent the deposition of particles of this size. In other words, to prevent the dragging of particles at the bottom, the length of the course should not be greater than a certain number of times the depth of the basin.

The data at hand for the strength of current which prevents the deposit of sand and gravel particles are not very good. From such data as are at hand it would seem that the value of f is from 20 to 40, and the corresponding length of the course, in proportion to the depth of the basin, is from 30 to 60. This computation, obviously, can be only applied to high velocities and large particles, and it has only a suggestive value in relation to the lower velocities and smaller particles discussed herein.

The conditions which have actually been used are easily learned. There is found in the basins to be mentioned later: At Little Falls, a basin in which the length of the course is but three times its depth; basins at Ithaca and Watertown, with courses about twenty times their depths; basins at St. Louis and Albany, with courses about fifty times their depths; and at Kansas City, a basin with a course more than eighty times its depth. There are other cases, no doubt, particularly where baffles have been used, where the ratios are even higher. It is unfortunate that it is not known whether or not the practice in these cases has been well founded, and whether the basins mentioned present conditions of sufficient repose so that particles stay down when they hit the bottom, or whether the bottom velocities are such as to keep the smallest particles moving even after they hit, and so limit the action to the removal of coarser particles.

Proposition 9.—Assume a very shallow sedimentation basin.

The most common method of expressing the size of a sedimentation basin is to state the length of time that it takes water to pass through it, or, more accurately, the quotient obtained by dividing the capacity of the basin by the quantity of water entering or leaving it in a unit of time. There has been a feeling, which was expressed by Sedden, and by others, that the area rather than the capacity of a basin measures its usefulness. In all the formulas deduced herein, the completeness of removal is a direct function of $\frac{a}{t}$. The effect of the area and depth of basin on the value of this ratio will now be examined.

Let b = the area of a basin;
c = the capacity of a basin;
d = the depth of a basin;
e = the quantity of water treated in a unit of time;
v = the hydraulic value of the sediment, or, in other words, the velocity at which it settles in still water.

$$\text{Then } a = \frac{c}{e} = \frac{b\,d}{e}$$

$$\text{and } t = \frac{d}{v}$$

$$\text{Combining, } \frac{a}{t} = \frac{\frac{b\,d}{e}}{\frac{d}{v}} = \frac{b\,v}{e} \quad \ldots\ldots\ldots\ldots (7)$$

In other words, the proportion of sediment removed is a function of the area of the basin and of the hydraulic value of the sediment, and of the quantity of water treated in a unit of time, and is entirely independent of the depth of the basin. This is true of all the propositions which have been considered herein. A very shallow basin will thus do precisely the same work as a deeper one of the same area.

An interesting deduction can be drawn from Equation 7:

$$\frac{a}{t} = \frac{b\,v}{e}$$

Now, $\frac{e}{b}$ represents the upward velocity which would result from the uniform upward flow of the water through the horizontal area of the basin, and the value of $\frac{a}{t}$ can be found by dividing the hydraulic value of the particle, represented by v, by this computed upward

velocity; and conversely, the hydraulic value of particles removed to an extent corresponding to an assumed value of $\frac{a}{t}$ can be obtained by multiplying this computed upward velocity by the assumed value of $\frac{a}{t}$. This gives a means of computing the results which may be expected from a given basin, which does not involve a knowledge of its depth.

The only way in which the depth influences the efficiency of sedimentation is in preventing bottom velocities too great to allow the deposition of sediment. It is obvious that depth has an important bearing in this respect; for, as was shown in Proposition 8 (with some limitations), the longest horizontal length of a course which can be allowed is directly proportional to the depth, and too little depth would limit the size of the basins to impracticably small dimensions.

Proposition 10.—Assume that the water passing through a sedimentation basin flows at the top in a thin layer and that the water below this layer remains quiet or nearly so.

This condition may be caused by a rise in the temperature of the entering water which will tend to keep it at the top. This, practically, has the effect of making a shallow sedimentation basin. But, by Proposition 9, a shallow basin is as effective as a deeper one, as long as the bottom velocities do not prevent the deposition of sediment.

In this case the bottom velocity is upon the still water below, and not upon the actual bottom of the basin. The line between the moving water and the quiet water must necessarily be somewhat indefinite, and the still water below forms an almost ideal receptacle for the particles which settle from the water above. The basin, therefore, will do all the work that it could do if the flow extended to the bottom, and, in addition, the question of bottom velocities is eliminated. This condition seems so attractive as to suggest the desirability of putting low baffles on the bottom of sedimentation basins to hold the water for some distance above the bottom still, or comparatively so, and to confine the current to the upper part of the basin.

Proposition 11.—Assume that the water passing through a sedimentation basin flows in a thin layer upon the bottom and that the water above this layer remains quiet, or nearly so.

This condition may be caused by a fall in the temperature of the

entering water which would tend to keep it at the bottom. This, pracically, has the effect of making a shallow sedimentation basin, but the question of bottom velocities is made more difficult, for the current is near the bottom and is more rapid than it would be if the flow were uniform. This condition may thus greatly reduce the efficiency of sedimentation.

Proposition 12.—Assume a sedimentation basin with skimmers to take the water equally from the surface at all points, and an upward flow in the basin to the top, the incoming water being distributed near the bottom.

The first clearing of the water in the process of sedimentation is at the top. It occurs almost instantaneously. If it were possible to remove this water from the top as fast as cleared, and before it had a chance to mix with the more turbid water below, a great improvement could be obtained over the conditions previously assumed.

To make the process effective, it would be necessary to provide skimmers to skim the entire area of the basin. This idea was first expressed in the Rockner-Rothe sewage precipitation tanks, built in Germany, fifteen years ago or more, and an example of which was erected at the World's Fair in Chicago in 1893. A more recent application is found in the Denver Water-Works.* If this arrangement could be developed to its theoretical limit, it would give a removal of sediment corresponding to Line *A*, which is the ultimate theoretical limit. It is not possible to reach this, because even with the best skimming there will be some mixing and consequent drawing from below the surface. The Line *B* is drawn as representing probably as close an approach to the theoretical as could be reached with the best system of skimmers. This line shows clearly the advantage of this process of drawing.

In many cases skimmers have been provided to take water from the top, but such skimmers have usually been located at a point, or at a few points, and, in these cases, unless differences in temperatures prevent, water is drawn to them from all directions, from the bottom as well as from the top, and the skimmer only serves to take the surface water from a small circle in its neighborhood, probably not much greater in radius than the depth of the water.

Proposition 13.—Assume that the sediment, instead of consisting of particles of the same hydraulic value, consists of particles which settle at different velocities.

---

* *Engineering News*, Vol. 44, p. 322.

If all particles which settle at the same rate be considered as belonging to one class, each class will follow its own law of deposition and will go down at the rate at which they would go if the other particles were not present. In making this assumption all matters of coagulation and flocculation are excluded.

The hydraulic values of particles of different sizes can be taken, and the value of t can be computed for each size. The value of a will be the same for all. The values of $\frac{a}{t}$ can then be obtained, and they will be inversely proportional to the hydraulic values of the particles of various sizes. Taking, then, the curve in Fig. 1 corresponding to the type of basin which is being considered, the corresponding value of x for particles of each hydraulic value can be found; that is to say, the percentages of the particles of those sizes remaining after the treatment. In this way, if a mechanical analysis of the sediment in the raw water were available it would be possible to compute the mechanical analysis of the sediment in the effluent.

Another way is to compute the size of the smallest particles removed by a given set of conditions. To do this it is necessary to assume some percentage of removal which shall be taken as sufficient. This percentage, of course, is arbitrary. It would hardly be taken as less than one-half nor more than seven-eighths. Perhaps three-fourths would answer the purpose. The sizes of particles removed in other proportions will always bear about the same relations to the size selected. That is to say, if the particles of which 75% are removed are taken as having a diameter of 1.00, then 50% of the particles having diameters of 0.78 will be removed, and 87½% of the particles having diameters of 1.47 will be removed. These figures are based on the use of Line *4* and upon Table No. 1, and are for particles less than 0.03 mm. in diameter. For coarser particles, and with other types of sedimentation basins, the proportion would vary slightly. It will be seen that, considering the great range in size of particles of sediment, the sizes do not vary very greatly, and the size computed in this way may be taken as roughly representing the size of removal. That is to say, it is such a size that particles larger than it will be removed and particles smaller than it will remain. The method of computing this size was stated under Proposition 9.

Proposition 14.—Assume that a sedimentation basin is divided by horizontal plates into two or more compartments, one above another.

As the action of a sedimentation basin is dependent upon its area and not upon its depth, one horizontal subdivision would provide two surfaces to receive sediment instead of one, and would double the amount of work that could be done. Two such divisions would treble it, and so on. If the basin could be cut up by a series of horizontal plates into a large number of shallow passages, the increase in efficiency would be very great. The matter of bottom velocities would have to be carefully looked after, and the ratios of length to depth, the depth in this case relating to each compartment, would have to be maintained. That is to say, the apparatus must be arranged so that the whole process takes place in a short distance of flow, this distance being proportional to one of the spaces between the plates. Such an apparatus may be called a scrubber.

The most serious practical difficulty to be met in carrying out this idea is the method of cleaning. The whole apparatus must be subject to easy and cheap cleaning. Cleaning will be required much more frequently, because, with the depth reduced to a low figure, the quantity of water passed through a given space in a given time would be correspondingly increased, and with it the amount of sediment deposited. If a sedimentation basin 10 ft. deep requires to be cleaned once a year, there would be a corresponding necessity for cleaning a scrubber with spaces of 1 in. between plates 120 times a year, or daily or oftener when the water was turbid.

Proposition 15.—Assume that turbid water is passing through a layer of sand, as in the ordinary process of filtration, and that sedimentation is taking place in all the pores, and that no other influence is at work to remove the sediment.

In this case the sediment is deposited on the surfaces of the sand particles facing upward at places where the current is not strong enough to prevent deposition.

Assume a layer of sand 1 m. thick, with an effective grain size of 0.35 mm., through which water is passing at a rate equal to 3 m. in depth over the surface daily. This rate of filtration is equal to a movement of the water column above the sand of 0.0347 mm. per second. The voids are about 40% of the whole volume. If the pores were all straight and cylindrical from top to bottom, the velocity of the water in them would be $0.0347 \div 0.4 = 0.087$ mm. per second. If 50% is added to represent the increased length of the passages because they are not straight, the velocity would be 0.13 mm. per second.

Experiments have been made in passing solutions of salt and water alternately through sand, which show that in the passage of water through sand a large part of the water in the sand has a low velocity, while a small part has a much higher velocity, so that a part of any given lot of water will make its appearance in a fraction of the time which would be required if the displacement were complete. In other words, some of the passages in the sand are large and comparatively direct, and in them the water moves more rapidly than the average, while the other passages are smaller and less direct, and in these the movement is slower than the average.

If it be assumed that two-thirds of the water in the sand is practically quiet, and that the forward movement takes place in the pores representing one-third of the total volume, the average velocity in these pores will be three times as great as computed, or about 0.4 mm. per second. As the individual pores are, at most, only a fraction of a millimeter in size, it appears that where the velocity is greatest, a given particle of water will pass through a single pore in a period of time which may be roughly stated as a little less than a second. On the other hand, in the smaller pores, where the movement is less rapid, the water may remain in one pore for several seconds.

The velocity of 0.4 mm. per second would not prevent the deposition of large particles of sediment, but such particles are removed at the top by simple straining, and the particles removed by deposition in the sand pores would only be very small particles, and this velocity might be too great to allow this subsidence. In the side passages, however, with lower velocities, conditions for subsidence would be much more favorable. Regarding the sand as a sedimentation basin, it is somewhat analogous to a long series of compartments connected at one side only, with a passageway in which a current is maintained. The bulk of the movement is in the passageway, but there is always some circulation to and from the chambers, which keeps up the supply of sediment particles in them and affords opportunities for sedimentation, and the whole should act as a sedimentation basin, even though the velocity in the channel is too rapid to allow subsidence.

The area of the surface of the sand grains, of sand of the effective size mentioned above, which is about the size commonly used in water filters, is surprisingly large. It is approximately equal to 5 sq. m. per kilogram of dry sand, and the surface area of particles in 1 cu. m. of sand is about 8 000 sq. m. In other words, in a layer of sand 1 m.

thick, the area of the sand particles is 8 000 times as great as the area of the space occupied by the sand.

Assume that, of the total surface area, one-sixth is placed horizontally and facing upward, or near enough to this position to make it capable of receiving sediment. Assume, further, that half of this area is in contact with other sand grains, or too near them to be available. Assume, further, that one-third of the remaining area will be so placed that the water passing it will have a velocity in excess of the rate which would allow the deposition of the finest particles. This reduces the area available for receiving sediment to $\frac{1}{6} \times \frac{1}{2} \times \frac{2}{3} = \frac{1}{18}$ of the whole area of the sand grains, or to an area 444 times as great as the area of the space occupied by the sand. In other words, the opportunities afforded for sedimentation are equivalent to those in a sedimentation basin with an area 444 times that of the filter, or to a basin equal to the filter in area and with 444 horizontal divisions, each capable of receiving sediment. The velocity of a column of water of the same area as the space occupied by the sand amounts to 0.0347 mm. per second. Dividing this by 444, it is found that the upward rate over the area capable of receiving sediment is 0.000077 mm. per second. Assuming (Line *D*) a value of $\frac{a}{t} = 1.4$, with 75% removal, the hydraulic value of the corresponding particles becomes 0.000108, and the diameter of particles corresponding to this (as will be shown in a subsequent paragraph) is 0.0003 mm. In other words, considered as a sedimentation basin, filter sand of the ordinary coarseness and depth, and at about the ordinary rate of filtration, would remove the bulk of all particles more than 0.0003 mm. in diameter. The finest clay is said to consist of particles about 0.0001 to 0.0003 mm. in diameter. A filter would thus fail to remove the finest clay, but would remove all coarser sediment. This conclusion agrees precisely with the facts.

If the rate of filtration is increased, the hydraulic value of the particles which are removed will be increased in the same ratio that the rate is increased; while, if the size of the sand grains is increased, the area of the surface of the particles will vary inversely as the effective size, and the hydraulic value of the particles which can be removed will increase directly with the effective size of the filtering material.

The hydraulic values of the particles which can be removed will thus vary directly with the rate and directly with the effective size of the filtering material. Assuming that the hydraulic value of the particles increases as the square of the diameters, this relation can be stated thus: The diameter of particles removed

$$= c \sqrt{\text{effective size of sand} \times \text{rate of filtration.}}$$

The value of c, in this equation, is found to be approximately 0.0003. The diameters of the particles removed are as follows:

For sand filters of standard construction, sand 0.33 mm. effective size, rate 3 000 000 galls. per acre, the greatest size of particles passing is 0.0003 mm.

If the rate of filtration is increased to 8 000 000 galls. per acre daily, the greatest size of particles passing is 0.0005 mm.

In a mechanical filter without coagulant, and with the same sand, at a rate of 130 000 000 galls. daily, the largest particles passing would be seven times as large as those removed with a sand filter, or 0.0020 mm.

In a scrubber containing gravel, with an effective size of 10 mm., and operated at a rate of 50 000 000 galls. per acre daily, the largest particles passing would be 0.0070 mm.

This size corresponds substantially with the computed size of removal by the sedimentation basins at Albany and St. Louis, and, as far as this computation indicates, a scrubber of this construction would be equivalent in its effect upon the water to the sedimentation basins in use in those cities.

In considering the probable course of sedimentation in sands and gravels one is naturally influenced by knowledge of the action of water in larger spaces and at higher velocities. It must be remembered that in the capillary spaces of the sand the viscosity of the water is of controlling importance, and the principles of flow are different from those with which one is familiar from experience with larger masses.

The purification of water in filters and scrubbers is probably influenced by the flocculation of particles, by surface attractions, by the presence of organisms and, very likely, by other influences of which nothing is known. It is impossible to determine what part, if any, sedimentation plays in the ultimate effect obtained under these conditions, but it is interesting to find that the results computed by the appli-

cation of the formulas deduced for sedimentation basins give results apparently in agreement with the facts observed in filtration; and, therefore, it is not irrational to suppose that sedimentation in the pores of these materials may play an important part in the results obtained.

On the Velocity at which Particles of Sediment settle through Still Water.

The larger particles settle rapidly, the smaller ones very slowly. With very small particles the viscosity of water controls, and the velocity of settlement, or the hydraulic value, varies as the square of the diameter. With large particles friction controls, and the velocity or hydraulic value varies as the square root of the diameter. There is a transition space between. This space covers particles from 0.1 to 1.00 mm. in diameter, or ordinary sand, and also extends somewhat beyond these limits.

TABLE No. 1.—Velocities at Which Particles of Sediment Fall in Still Water.

Diameter of particles, in millimeters.	Hydraulic value, in millimeters per second. 10°C. — 50°F.	Remarks.
1.00	100	Experiments by the writer.
0.80	83	" " " "
0.60	63	" " " "
0.50	53	" " " "
0.40	42	" " " "
0.30	32	" " " "
0.20	21	" " " "
0.15	15	" " " "
0.10	8	" " " "
0.08	6	Interpolated from connecting curve.
0.06	3.8	" " " "
0.05	2.9	" " " "
0.04	2.1	" " " "
0.03	1.3	" " " "
0.02	0.62	Wiley's formula.
0.015	0.35	"
0.010	0.154	"
0.008	0.098	"
0.006	0.055	"
0 005	0.0385	"
0.004	0.0247	"
0.003	0.0138	"
0.002	0.0062	"
0.0015	0.0035	"
0.001	0.00154	"
0.0001	0.0000154	"

Note.—These values are not given as being precise, but they are believed to be sufficiently accurate for the purpose of this discussion.

The hydraulic values of particles within these limits have been determined by noting the time required for settlement for a determined distance through water in a glass vessel. Particles of different sizes were obtained by the methods used in the mechanical analysis of sand. The specific gravity of the particles is about 2.65. The grains are irregular, and the diameters are taken as the diameters of spheres of equal volume.

For particles less than 0.025 mm. in diameter, the formula given by Wiley * is used, namely, $d = 0.0255v^2$, the diameter being in millimeters and the velocity in millimeters per second. The hydraulic values of particles from 0.025 to 0.1 mm. in diameter have been obtained by drawing a curve between the lines representing the higher and lower values. Some of these values are given in Table No. 1.

On the Effect of Temperature.

The figures in Table No. 1 are for a temperature of 10° Cent., or 50° Fahr., which is about the annual average temperature of the water in the northern part of the United States. The finer particles settle more rapidly as the water becomes warmer, but with the coarser ones temperature makes less difference. For the finest particles, the rate of settling at different temperatures varies as $\frac{t + 10}{60}$, t being the temperature on the Fahrenheit scale. The relative hydraulic values of the same particles at different temperatures are as follows:

Temperature, Fahrenheit.	Relative Hydraulic Value.
32	70
38	80
44	90
50	100
56	110
62	120
68	130
74	140

At a summer temperature of 74°, a particle of sediment will settle twice as fast as at the freezing point. In other words, a given sedimentation basin will do twice as much work in summer as in winter. Experience indicates the truth of this deduction, and it is also true of filters.

* "Agricultural Analysis," p. 212.

On the Effect of Flocculation and Coagulation.

By flocculation is understood the gathering together of the particles of sediment into aggregates. This takes place more or less with clayey sediment. It is probably not a very important matter in sedimentation basins, because the opportunities for it in rivers before the water enters the sedimentation basins have been so favorable that it has gone as far as it will readily go before the water enters the basin.

Coagulation is artificial flocculation, and is caused by the addition of a chemical to the water. The effect of flocculation or coagulation is to increase the size of the particles, for the aggregates formed in this way have subsiding values which may be very much larger than the subsiding values of their individual particles. Salt water induces flocculation, and the increased rate of sedimentation when fresh water mixes with salt water is to be explained in this way; for it cannot be supposed that an individual particle would settle faster in salt water than in fresh.

Comparison of Different Arrangements of Settling Basins.

The values of $\frac{a}{t}$ necessary to secure the removal of one-half, three-fourths and seven-eighths of the particles of a given size, with basins of different arrangements, and without regard to excessive bottom velocities, are given in Table No. 2.

TABLE No. 2.

Description of basins.	Line in Fig. 1.	Values of $\frac{a}{t}$. One-half removed.	Three-fourths removed.	Seven-eighths removed.
Theoretical maximum (cannot be reached)	*A*	0.50	0.75	0.875
Surface skimming, Rockner-Roth system	*B*	0.54	0.96	1.37
Intermittent basins, reckoned on time of service only	*C*	0.63	1.26	1.89
Continuous basin, theoretical limit	*D*	0.69	1.38	2.08
Close approximation to ditto	*16*	0.71	1.45	2.23
Very well baffled basin	*8*	0.73	1.52	2.37
Good baffling	*4*	0.76	1.66	2.75
Two basins tandem	*2*	0.82	2.00	3.70
One long basin, well controlled	*1 1/2*	0.90	2.34	4.50
Intermittent basin, in service half time	*E*	1.26	2.50	3.80
One basin, continuous	*1*	1.00	3.00	7.00

The figures given in Table No. 2 under the respective headings represent the relative areas of sedimentation basins upon different systems which would be required to produce equivalent results. It will be noticed that the differences between the different systems are always in the same order (with the exception only of the intermittent basin with the allowance for time out of service), but the relative values are different for different percentages of removal. With the removal of one-half of the particles of a given size the differences are less than for the removal of three-fourths of the particles, and for the removal of seven-eighths of the particles the differences are greater.

From the standpoint of preliminary treatment, there would be something to be said in favor of taking a removal of one-half of the sediment of a given size as a standard, because that would represent the bulk of the material; while, from the standpoint of entire clarification, the removal of seven-eighths would be better. The use of the value corresponding to three-fourths removal seems a fair one for a general discussion.

The application of the different lines shown in Fig. 1 to actual sedimentation basins will now be considered. Obviously, the conditions in these basins are more complex than those assumed in the propositions from which the equations of the lines were deduced. Nevertheless, the propositions may represent a sufficiently close approximation to the facts to be of practical use.

Sedimentation basins operated on the intermittent plan seem to meet reasonably well with the assumptions which led to Line *C*, and this line may be taken as representing the conditions in such basins. Sedimentation basins with one compartment and with the water introduced at one point and taken out at another, without any special precautions to distribute it and reduce its velocity, may clearly be taken as being represented approximately by Line *1*. Basins of this type include the St. Louis basins, as they were used two or three years ago, that is, with water entering continuously at one end and flowing out at the other. A sedimentation basin like that at Little Falls, with the water entering at the bottom and taken out at the top at the opposite side, presents a peculiar condition because its depth is so very large in proportion to its length that the removal of the water from the top, even though limited to one side, may be equivalent to a surface straining of a considerable part of its area. Where several

basins are used successively, as at Kansas City and Omaha, the lines having a number corresponding to the number of such basins may be taken directly as representing the conditions. In the case of a very long and narrow basin, the conditions are somewhat different. There is a tendency for the different sections along the length of the basin to act as though they were separate basins. That is to say, there is only a limited amount of circulation between the different parts, and if the process were carried far enough the basin would act as if it were composed of a large number of basins used successively. The sedimentation basins for sewage, designed by Lindley at Frankfort-on-Main, were of this type. Clearly, they are equivalent to several basins, but it is impossible to say how high a number should be assumed. Sedimentation basins for water purification designed upon this principle have seldom been used.

Where the water is introduced very carefully at one end or side of a basin and removed at the other side by a corresponding arrangement, the conditions should be materially improved over those of a single basin, and a line intermediate between *1* and *2* may be used.

Baffling a sedimentation basin consists in building light walls or partitions in it, partially dividing it into a number of compartments. The division is only partial, but it serves in large measure to prevent circulation between the different successive compartments. With very numerous baffles, a sedimentation basin would evidently be cut up so as to be equivalent to a large number of basins used successively. Practically, a basin must not be cut beyond the point which is limited by the allowable bottom velocities, and, except in particular cases, Line *4* may perhaps be taken as representing a practical limit to the results obtained in this way. Under very favorable circumstances, the results indicated by Line *8* might be reached.

Keeping the foregoing classification in mind, the figures in Table No. 2, for the values of $\frac{a}{t}$ for three-fourths of the sediment removed, indicate the relative areas of basins of the different types required to produce equivalent results. It will be seen that a well-baffled basin, corresponding to Line *4*, will do as much work as a single basin with nearly twice the area, where mixing throughout the whole volume is allowed. Intermittent basins, allowing for the time out of service, do only slightly more efficient work than single basins operated continu-

ously, and, with the most rudimentary baffling, with the continuous system, puts the efficiency above that obtained on the intermittent system.

The theoretical efficiency of the surface skimming is well shown, and only the practical difficulty and expense of carrying out this method limits its use.

Application to a Number of Basins in Use.

The principles and results of these discussions may be better understood by applying them to a number of practical cases. The dimensions have been taken in some cases at approximate figures, and the quantities of water assumed as passing are nominal. In several cases they have been taken as the capacities of the plants, in other cases as the approximate quantities recently treated. The quantity of water treated obviously affects the results materially. In some cases where plants have been operated at much less than their nominal capacities the actual results have probably been correspondingly more favorable.

Several coagulation basins, used in connection with mechanical filters, are included. The primary purpose of these basins is to allow the necessary time for the chemical changes to take place, but the process is facilitated by having them act as sedimentation basins, and it is therefore fair to discuss them in this way. Of course, in these cases, the material removed is of a flocculent nature, very different in its subsiding value from the sand and silt which is taken as the basis of the computation; and the sizes given, therefore, are the sizes of sand particles of equal hydraulic value, and not the actual sizes of the flocculent particles.

Table No. 3 is a statement of the data, and the computations regarding a number of basins.

The results shown in Table No. 3 are very striking. The system of reservoirs at Washington should remove particles to 0.003 mm. in diameter, although the horizontal courses are so long that bottom velocities may limit the results. The Kansas City basins remove particles to 0.005 mm. The St. Louis and Albany basins remove particles down to 0.007 mm. in diameter. The results from the coagulating basins at Ithaca and at Watertown are close together, with removals of 0.018 mm. The Warren tank, at Pittsburg, removed particles down to 0.034 mm. and the Jewell down to 0.047 mm. The basin at Little

Falls gives the poorest sedimentation of all, being only able to remove particles more than 0.077 mm. in diameter, which is coarse silt or very fine sand. The latter must be regarded as a coagulation basin, only, and it is obvious that the sedimentation which takes place in it must be very limited.

Résumé.

The fundamental proposition, in clearing water by sedimentation, seems to be that every particle of sediment moves downward through the water at a velocity depending upon its size and weight and upon the viscosity of the water. Particles of sediment are generally so far apart that they do not influence each other; and, while there is no doubt that they do sometimes collect in groups and thus change the conditions, it seems to be generally true that each particle will settle as if no other particles were present.

If the water in a basin were absolutely quiet there would be a regular sequence of clearing beginning at the top. The coarsest particles would go down fastest, but at any given point there would be a gradual clearing, and this clearing would take place most rapidly at the top, and, after longer intervals, at lower points in the basin.

Sedden started out with this theory, but found it to be not in accordance with the facts. His observation showed that while the amount of sediment in the water in the top was a little less than in the water in the bottom, the distribution was nearly equal throughout the mass, a condition of affairs inconsistent with the theory. He accounted for this distribution of sediment by the constant mixing of the water from top to bottom, and to the sustaining power of vortex motions in the water. These motions he thought arose from the internal motion of the water at the time of entrance, and from wind, and from temperature changes.

The writer has taken Sedden's development of the case as his starting point, and has carried the discussion further. He believes that while the internal motions keep the water mixed, and with nearly the same density of sediment from top to bottom, the tendency of the particles of sediment to settle is nevertheless an unbalanced force always acting to take the particles to the bottom, and the number of particles that hit the bottom in a given time is proportional, first to the velocity at which the individual particles settle, add second to the density of sediment in the water immediately above the bottom.

TABLE No. 3.—SEDIMENTATION AND COAGULATION BASINS.

Basin.	Area, in square feet.	Average depth, in feet.	Approximate horizontal course, in feet.	Ratio of horizontal course to depth.	Quantity treated daily, in gallons.	Hours of storage.	Gallons per square foot, daily.	Horizontal velocity, in millimeters per second.	Millimeters in depth of water removed per second.	Type of basin.	Value of $\frac{t}{a}$ for 75% removal.	Hydraulic value of smallest particles removed.	Diameter of smallest particles removed, in millimeters.
East Jersey	5 400	43	130	3	32 000 000	1.30	5 920	8	2.78	Special	2.00	5.56	0.077
Jewell, Pittsburg	181	6.7	....	....	250 000	0.68	1 910	....	0.90	*1*	3.00	2.70	0.047
Warren, Pittsburg	176	10	....	....	300 000	1.05	1 700	....	0.80	*2*	2.00	1.60	0.034
Ithaca	4 700	11.4	240	23	3 000 000	3.20	638	6	0.30	*4*	1.67	0.50	0.018
Watertown	9 880	13.6	270	20	6 000 000	4.00	610	6	0.286	*4*	1.67	0.48	0.018
World's Fair, Chicago, 1893, sewage	3 136	40	....	....	2 400 000	9.00	768	....	0.360	*B*	1.00	0.35	0.015
Albany	220 000	8.5	400	47	17 000 000	20.00	77	2	0.0363	*1 1-2*	2.33	0.084	0.007
Experimental sand filters, Pittsburg	670	6.8	45	7	34 000	24	51	0.2	0.0240	*1*	3.00	0.072	0.007
St. Louis	1 600 000	14	750	54	80 000 000	50	50	1	0.0236	*1*	3.00	0.070	0.007
Kansas City	300 000	20	1 700	85	15 000 000	72	50	2	0.0235	*4*	1.67	0.039	0.005
Washington	6 690 000	14	8 000	570	75 000 000	225	11	3	0.0053	*4*	1.67	0.009	0.003

With these fundamental relations in mind, it
and to express by simple formulas the proportions
ment of a given hydraulic value which will hit the
conditions and which, therefore, presumably, will

The fundamental propositions may be very co
They are: First, that the results obtained are de
area of bottom surface exposed to receive sediment
entirely independent of the depth of basin; and se
results are obtained when the basins are arranged s
water containing the maximum quantity of sedi
mixing with water which is partially clarified. I
best results are obtained where any given lot of w
the basin with the least mixing with the water wh
it, and with the water which enters after it. Thi
complished by dividing the basins into consecut
baffles or otherwise.

Thus far, the discussion is easy and apparently
step is a more difficult one. It relates to bottom ve
do with the question whether these velocities are s
particles to remain on the bottom when they get
they will be taken up again and be kept in motio
the water. This is a point upon which further exp
needed. The problem of securing such data see
The observations must be made at the bottom of a
considerable thickness, where the conditions of o
favorable. The observations, further, must be mad
cities and on particles so small as to be practically

Whatever view may be taken of the second part
whatever researches upon it may show, the arrangem
favorable to taking particles to the bottom should

The computations made in this paper show the
forms of construction already successfully used, a
possible improvements in design.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE GATUN DAM.

By C. D. Ward, M. Am. Soc. C. E.

To be Presented May 18th, 1904.

In a paper,* entitled "Inter-Oceanic Canal Projects," by A. G. Menocal, M. Am. Soc. C. E., it is stated that the Government Commission, appointed in 1875, reported, as to a canal with locks, from Colon to Panama, as follows:

"The river (Chagres) is proposed to be crossed by means of an aqueduct having twelve spans of 90 ft. each, 1 900 ft. extreme length, 65 ft. wide and 26 ft. deep."

In discussing this paper,† the late Ashbel Welch, Past-President, Am. Soc. C. E., a thorough and noted canal engineer in his day, said:

"The first thought of an American canal and river engineer, on looking at M. de Lesseps' raised map, is to convert the valley of the lower Chagres into an artificial lake, some 20 miles long, by a dam across the valley at or near the point where the proposed canal strikes it a few miles from Colon, such as was advocated by Mr. C. D. Ward."

The site proposed for this dam was at Gatun, 7.5 miles from deep water at Colon, the end of the canal. But, as is well known, the use

* *Transactions*, Am. Soc. C. E., 1879, Vol. VIII, p. 311.
† *Transactions*, Am. Soc. C. E., 1880, Vol. IX, p. 148.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

of locks was not to be thought of under M. de Lesseps domination, and a sea-level canal was commenced in 1883.

In 1887 it was at last decided that locks would have to be used, and from that time to the present, various locations and elevations for the necessary locks have been suggested and different sites for the great dam selected.

The New Panama Canal Company and the Isthmian Canal Commission of 1899, the latest authorities, agree in locating the dam near Bohio, 16.5 miles from deep water at Colon, or 9 miles farther up stream than Gatun, the location suggested by Mr. Welch in 1880.

Furthermore, the Isthmian Canal Commission says in its report that "no location suitable for a dam exists on the Chagres River below Bohio."*

The late George S. Morison, Past-President, Am. Soc. C. E., a member of the Isthmian Canal Commission, commenced his paper on the Bohio Dam, which was presented to this Society on March 5th, 1902,† with this sentence:

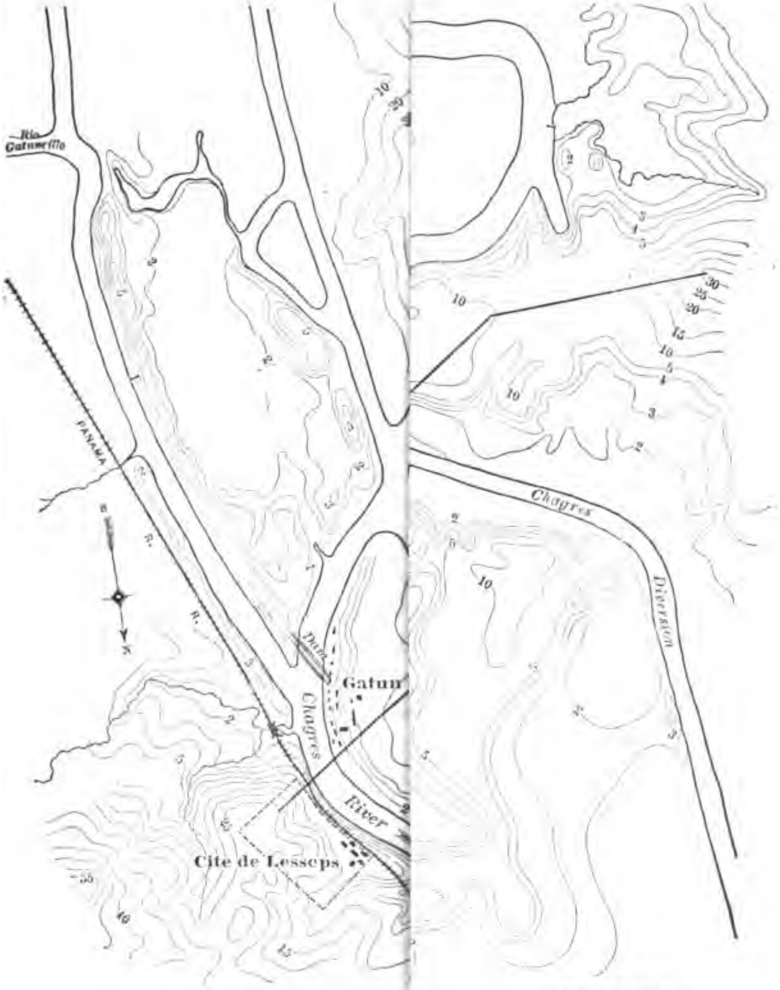
"All engineers who have examined the route of the Panama Canal agree that the neighborhood of Bohio is the only available location for the dam by which the summit level must be maintained."

Neither of these authorities mentions or gives any consideration to the project of a dam at Gatun, nor even condemns it; nor is the writer aware that any soundings or other examinations, looking to a dam at that point, have ever been made.

As this question may be worthy of more consideration than it seems to have received, some of its advantages may be stated. The canal, as proposed by the latest authority, the Isthmian Canal Commission, may be briefly described as follows: From deep water in Colon Harbor to the Bohio Locks, the Atlantic Maritime Level, cut mostly through the low flat valley of the Chagres, will be 16.81 miles long. The two Bohio Locks, with a lift of 45 ft. each, reach the Bohio Lake, formed by the Bohio Dam, with a maximum elevation of 90 ft. above tide in Colon Harbor and an area of 38.5 sq. miles. The summit level thus attained extends through the Culebra Cut. The distance from the Bohio Locks to the Culebra Cut is 13.61 miles, and from thence through the Culebra Cut to the Pedro Miguel Locks at the farther end of the level the distance is 7.91 miles. The maximum

* "Report of the Isthmian Canal Commission," 1899–1901, p. 90.
† *Transactions*, Am. Soc. C. E., Vol. XLVIII, p. 235.

PLATE XXI.
PAPERS, AM. SOC. C. E.
APRIL, 1904.
WARD ON THE GATUN DAM.



GATUN DAM.
PANAMA CANAL
Contours are in Meters
0 1000 2000 FT.
SCALE

combined fall of these two locks is 62 ft. From Pedro Miguel Locks a level of 1.33 miles extends to Miraflores Lock, which has a maximum fall of 38 ft. to mean low tide in Panama Harbor. For a distance of 4.12 miles beyond this lock the canal extends, through the low swampy country in which the Rio Grande flows, to a point known as La Boca, on the edge of Panama Bay. A dredged channel extends from this point 4.41 miles to the 6-fathom line in Panama Bay.

Allowing 0.90 mile for the various locks, the total length of canal is 49.09 miles.

As to the suggested dam at Gatun, the New Panama Canal Company has made a contour map of the region where the dam would probably be located, if at all. This map is reproduced as Plate XXI, and from it the writer has constructed a section on the proposed center line of the dam. This section indicates the surface of the ground, but, unfortunately, does not show the rock or other solid foundation. If a dam were built here, impounding the water to an elevation of 90 ft., then, of course, the Bohio Dam and the locks and spillway would be omitted, and locks would be built at Gatun.

The length of the dam would be 6 750 ft., while the length of the Bohio Dam is 2 546 ft. The area of the section is nearly three times that at Bohio; therefore, it might not be out of the way, for the present, to say that the cost of the Gatun Dam would possibly be three times that estimated for the Bohio Dam, or $19 108 920. At present, there seems to be no reason to think that the locks would cost more at one place than at the other, but the spillway should be somewhat longer, and might cost more. There may be a question whether the hills to the east of Gatun are high enough to contain the Gatun Lake at an elevation of 90 ft., but the raised map made by the New Panama Canal Company, a reproduction of which is to be seen at Columbia University, indicates sufficiently high ground. The lake would extend far up the valley of the Rio Gatun on the west and the Rio Trinidad on the east, and submerge the Chagres Valley for 9 miles, including the Aqua Clara, Pena Blanca, Vino Tinto and Bruja Swamps, cover 20 or 30 sq. miles of swampy land, and thus improve the healthfulness of the country. This lake area added to the 38.5 sq. miles of the Bohio Lake would be a benefit in every way and would render the Alhajuela Dam on the Upper Chagres unnecessary. Between Gatun and Bohio the excavation of the sea-level canal, the Pena

Blanca Swamp outlet to Aqua Clara Swamp, the Chagres diversion from Aqua Clara Swamp to near Gatun and the diversion of the Rio Gatun, would become unnecessary, and their cost would be saved. These items amount to $14 635 604, a sum large enough to pay the assumed extra cost of the Gatun Dam and leave about $2 000 000 to pay for changing the line of the Panama Railroad and the possible additional cost of the spillway. If these assumptions should prove practicable, the result would be a better and safer canal, shorter time of transit, and more healthy conditions, all at no greater cost and with lower maintenance charges.

If a dam at Gatun, with an elevation of 90 ft., were found inadvisable, one of 45 ft. elevation might be built and the Bohio Dam and Lake retained. Then the lower Bohio Lock would be omitted and established at Gatun and a spillway built there also. The cost of the 45-ft. Gatun Dam might be assumed at $12 000 000, about twice the estimated cost of the Bohio Dam. Its length would be 5 150 ft. The head on the Bohio Dam would be reduced from 90 to 45 ft., and the danger from seepage greatly reduced.

It seems quite possible that with this 45-ft. dam the total cost of the canal would be reduced a few million dollars below the figure named in the report of the Isthmian Canal Commission.

Turning from the Colon end of the Canal to the Panama end, it appears that from the Miraflores Locks to La Boca, a distance of 4.12 miles, the canal is to be excavated at sea level through a low swampy country, with occasional rock, at a cost of $10 963 458. It is suggested, as a plan worth consideration, that this lock be located at La Boca, that a dam and spillway be built there and that the 4.12 miles of swamp be thus flooded, thus affording better and safer navigation than would be had in a narrow channel. The main dam would probably be a mile long, with two or three shorter dams, and might cost no more than the excavation of the 4.12 miles of canal that would be saved. The malarial swamp would be submerged, also. With the 20-ft. rise and fall of tide at Panama, the inrush and outrush of the water in that 4.12 miles of sea-level canal might incommode navigation. All this would be done away with if the last lock was placed at La Boca.

Recurring to the suggested 45-ft. Gatun Dam, with its large lake, the plan of reducing the elevation of the summit level from 90 to 45 ft. may be briefly considered. This elevation is suggested, as 45 ft. seems to be the maximum permissible lift for a lock.

The elevation of 90 ft. for the Bohio Dam seems to have been selected with reference to flood control and in order that the resulting lake should have an area large enough to supply water for lockage, seepage and evaporation during the dry months, without too great a change in the elevation of the surface of the lake.

The 45-ft. dam at Gatun would be so much farther down stream that it might be expected to form as large a lake as the 90-ft. Bohio Dam and perform all the functions of the Bohio Lake.

With one lock at Gatun and one at La Boca, each of 45 ft. lift, the lockage would be reduced to a minimum, and rapidity and safety of transit would be secured. The cost of the modified project might be as follows:

Colon entrance and Harbor	$8 057 707
Colon Harbor to Gatun	942 293
Gatun Dam, Spillway and Locks	19 000 000
Lake Gatun, upper end to Obispo	20 000 000
Obispo gates	295 434
Culebra Section	63 500 000
La Boca Dam, Locks and Spillway	15 000 000
La Boca to deep water	1 464 513
Panama Railroad diversion	1 000 000
	129 259 947
Add 20%	25 851 989
Total	$155 111 936

The estimate made by the Isthmian Canal Commission, with the summit level at 90 ft., was $144 233 358.

The suggestions of 24 years ago have thus been elaborated and presented in this short paper in the hope that, in the discussion, it will appear whether examinations have been made, by any of the various commissions or others, as to the practicability of a dam at Gatun, and, if so, with what result.

If it should appear that such examinations have not been made, it is hoped that this paper will induce those in authority to make such examinations before deciding upon the final plans for the Panama Canal.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE COLLAPSE OF A BUILDING DURING CONSTRUCTION.

By H. de B. Parsons, M. Am. Soc. C. E.

To be Presented May 18th, 1904.

At the request of some of the members of the Society, the writer presents this brief description of the construction and collapse of the Hotel Darlington, with the object of bringing out a discussion which may lead to improvement in the designs of such buildings.

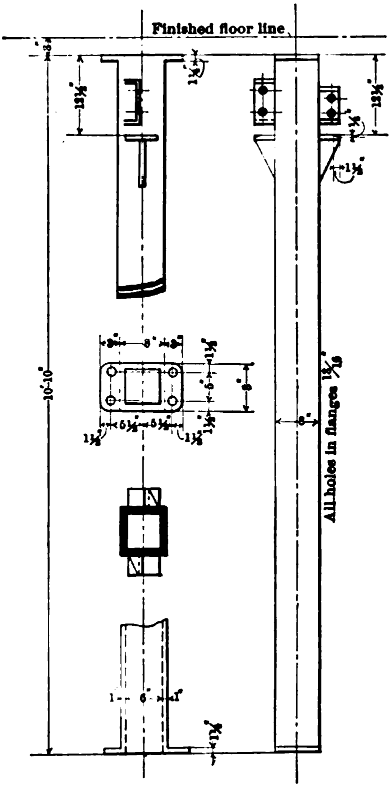
Construction.—The building was being erected on lots known as Nos. 59 and 59½ West 46th Street, Borough of Manhattan, City of New York. The land measured about 55 ft. in width by 100 ft. 5 ins. in depth. On the east and west sides, the adjacent buildings were of the ordinary construction for residences—of brick with brownstone fronts, four stories and basement in height.

The Hotel Darlington, as the new structure was to be called, was being constructed on the "cage" system, that is, all the weight was supported on the columns.

The outside walls were of brick, and partly concealed the exterior row of columns. These walls were continuous from the foundation, and did not rest on girders at the floor levels.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The columns were of cast iron, with end flanges, and with side brackets and lugs cast near the top to carry the girders. All the columns were of rectangular section, generally varying from 9 ins. square by 1 in. thick, in the basement, to 6 ins. square by $\frac{3}{4}$ in. thick on the upper floors. Each column had top and bottom flanges cast only on the north and south sides, and each flange had two bolts. Fig. 1 illustrates a typical column. The thickness varied with the column position in the building. Some of the 9-in. columns in the basement were $\frac{3}{4}$ in. in thickness. Fig. 2 illustrates a typical column foundation.



8 INCH COLUMN

Scale of feet

0 1 2 3 4

FIG. 1.

The girders and floor beams were of steel. The girders, generally, ran east and west across the building. They were supported on the brackets cast on the columns, and were bolted to the lugs with two bolts at each end. The beams, generally, ran north and south, and were bolted to the girders by double-clip angles with two or three bolts through each leg of the angles. The floor members were all of rolled sections—I's and channels—and many were marked "Phœnix and "Carnegie." Fig. 3 illustrates a typical floor plan and shows the location of the columns.

The floor arches were of cinder concrete, laid up on the Roebling system. The spans were variable, averaging from 4 ft. 6 ins. to more than 5 ft. The thickness of the arches could not be determined, as all of them were destroyed.

The building was to have been twelve stories and a basement in

height, with a penthouse, or one-story structure, pa
roof. Each floor was lettered, and the columns on t
ried in size. Table No. 1 is a specimen schedule.

TABLE No. 1.

Floor.	Letter.	Column.	
		Side.	Thickness.
Basement	*A*	9 ins.	1 in.
Ground Floor	*B*	9 "	¾ "
2d "	*C*	8 "	¾ "
3d "	*D*	8 "	¾ "
4th "	*E*	7 "	¾ "
5th "	*F*	7 "	¾ "
6th "	*G*	6 "	¾ "
7th "	*H*	6 "	¾ "
8th "	*J*	6 "	¾ "
9th "	*K*	6 "	¾ "
10th "	*L*	6 "	¾ "
11th "	*M*	6 "	¾ "
12th "	*N*	6 "	¾ "
Penthouse			
Height to under side of roof beams			

The construction had progressed until the metal w
floor had been erected complete, and some of the w
and eleventh floors was in place. The structure co
1.30 P. M., on Wednesday, March 2d, 1904.

Observations on the Wreckage.—On collapsing, t
downward with a leaning to the north, that is, tow
viewed from a sixth-story window in the Hotel Pa
immediately in the rear on 47th Street, the "cente
which all the various members pointed, more or les
the west of the center line of the building and a litt
a line drawn between the rear walls of the adjacent b
and 61 West 46th Street. Practically all the materi
cept a relatively small amount, which fell over the
and into the Hotel Patterson.

The columns in the outer walls broke off, with
formity, between the second and third floors, althou
tems of the stories below, and the interior columns
the basement) were carried away, leaving the outer c
from their foundations to the points of rupture. See

The columns were measured with calipers and showed a fair uniformity as to thickness of metal on opposite sides. The variation was about $\frac{1}{8}$ in. or less.

In the great majority of cases the columns broke at the flanges, leaving one or both of the broken flanges bolted to the corresponding

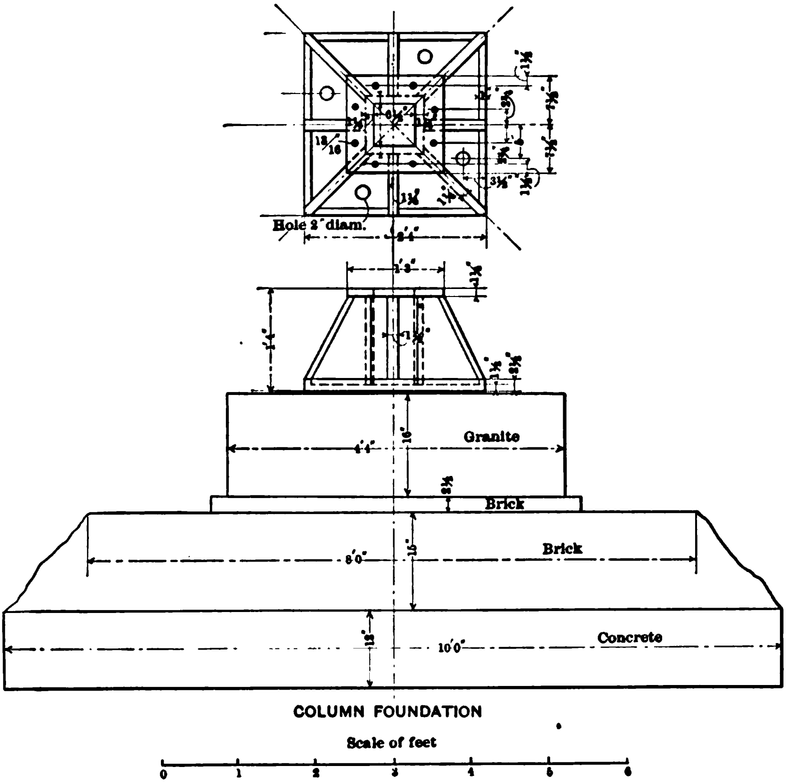


FIG. 2.

flange of the adjacent story column. A few of the columns were broken at or near the center.

There were no ribs cast on, to stiffen the flanges.

The column ends were faced. No shims were found between the ends of the columns.

The holes in the column flanges were drilled, $\frac{13}{16}$ and $\frac{7}{8}$ in. in diameter. The bolts were $\frac{3}{4}$ in., and some were loose. The holes in the

lugs for the girders were cast, and were about ⅞ in. holes in the girders were about ⅞ in. in diameter ¾-in.

The fractures in the body of the cast-iron colun good metal. The fractures at the flanges exhibit honey-combing in many instances. About 15% o honey-combed, about 25% were defective, and abou good. The defects did not show on the exterior sur varied from 1 in. to 1¼ ins. in thickness.

The rolled-steel members of the floor systems steel gave evidence of being good material, and th A number of pieces—I's and channels—were tak which, from the appearance of the bolt-holes, had Such pieces were marked for use on the 10th, 11t They were found chiefly on top of the ruins and March 6th about twenty-two unerected pieces were the morning. The weight of this unerected materi and three tons. Also, a broken piece of an 11th-st which had been erected, was taken out with them.

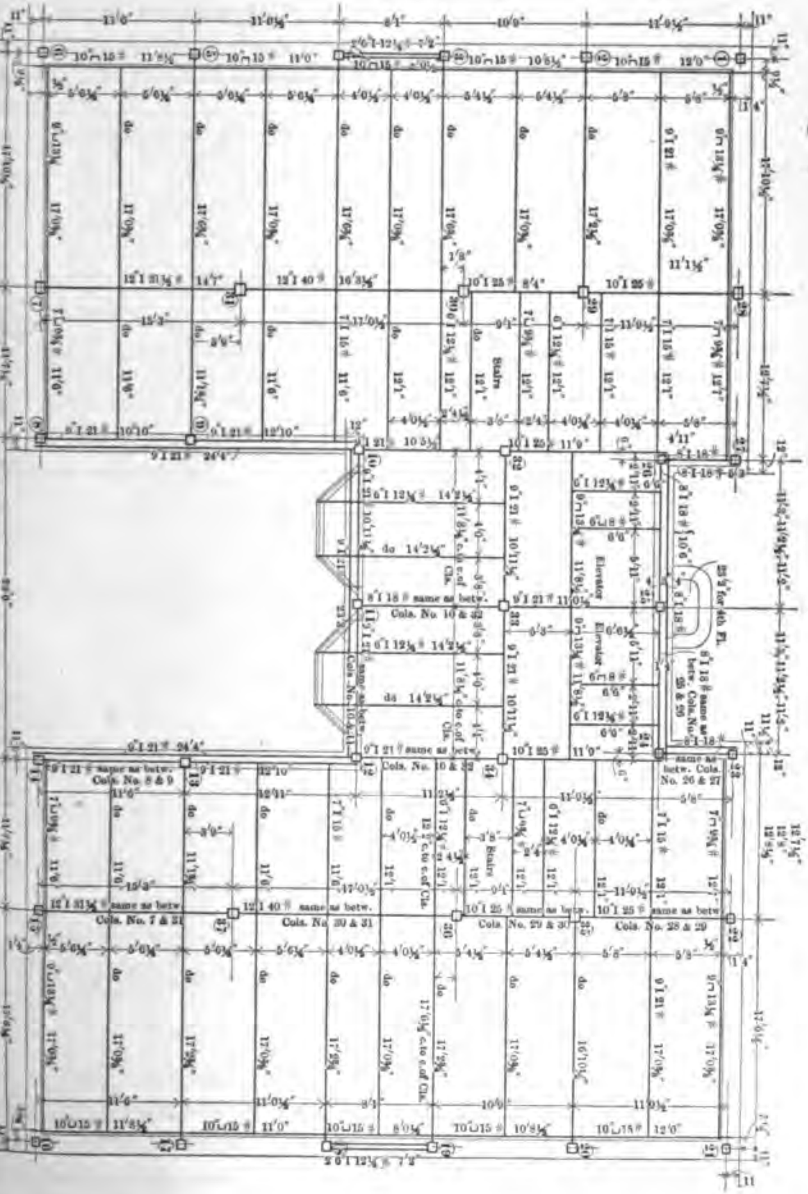
The concrete from the floor arches was broke larger than 12 x 12 ins. were found.

The foundations under the exterior and inte found true and level. The cast-iron shoes under th place and unbroken. The soil under the colum clay in every instance where dug up, both at the the lot. The foundations had an area of about 10 sufficient to have sustained the load intended.

Three hoisting engines and boilers were dug out paratively slightly injured. Their boilers were in

All members were bolted. Rivets were not us diagonal braces, corner braces, or any special mea lateral stiffness against wind or side pressure. held in their vertical positions by the floor syste bearing brackets.

Cause of Fall.—The bolts fastening the girders the column lugs were of smaller diameter than the columns received little or no lateral support. T were bolted together at top and bottom, and acted



TYPICAL PLAN OF FLOOR BEAMS FOR 3rd, 4th, 5th, 6th, 7th, and 8th, FLOORS.
WITH DIMENSIONS FOR THE FOURTH FLOOR.

umns. All the loads were eccentrically supported on
The columns were too long to carry the superimp
column situated at or near the "center of fall" (pre
broke. The upper part of this column, being depri

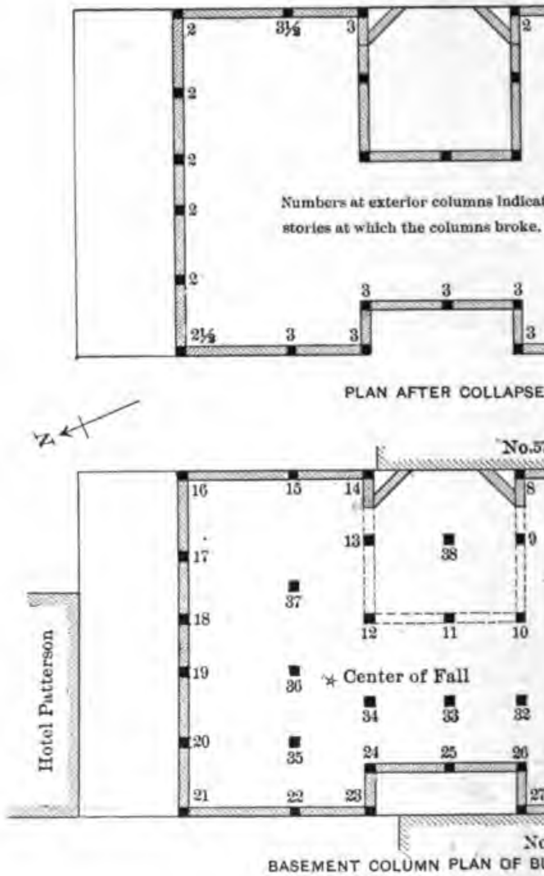
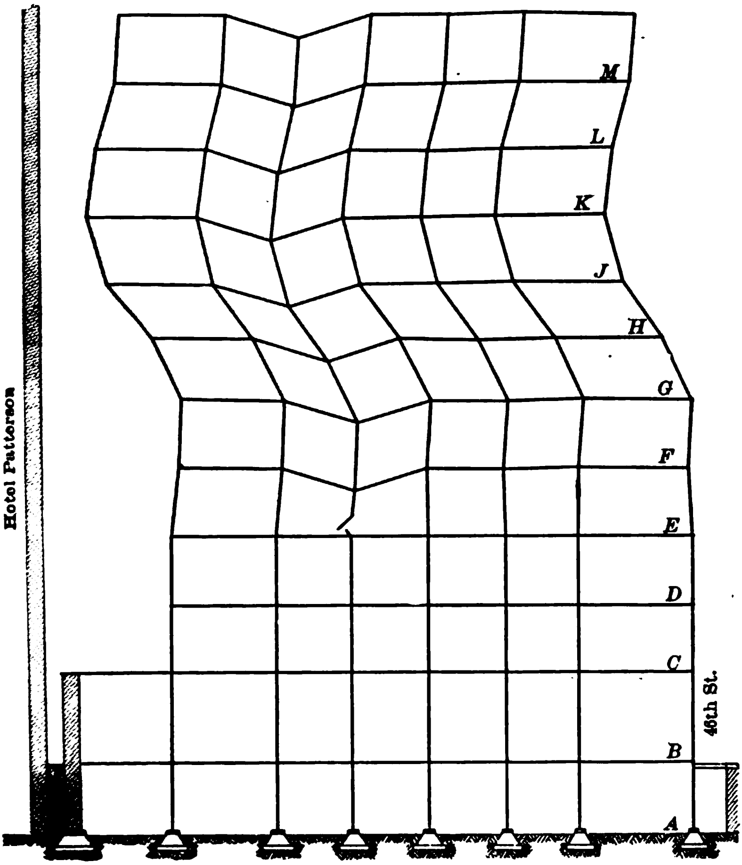


FIG. 4.

fell and pulled with it the floor members bolted to
floor members pulled over the adjacent columns t
ends were attached; and these columns, having n
broke at the lower flange, as the pull had a lever ar
or the length of the column. The above-described

of the stresses affected only those portions of the structure above the level of the original fracture.

In falling, the mass of material from above crushed down and broke that part of the structure below the level of the original fracture.



VERTICAL SECTION ILLUSTRATING METHOD OF COLLAPSE
FIG. 5.

The exterior columns did not break off as low down as the interior columns, because the mass fell away and did not crush them as it crushed the interior ones. The uniformity in height at which the exterior columns broke indicates strongly that the primary fracture occurred at or about the level of the fourth floor.

As proof that the top fell into and toward the "center of fall" before the lower part of the structure collapsed, columns G 11 and K 11 were taken out of the débris near the "center of fall" and from beneath other members which originally were connected at points lower down in the building. Near the same spot, column D 36 was found standing in a nearly upright position. Of these columns, the first was broken at the center, and the other two at the flanges.

Furthermore, as more of the structure was south of the "center of fall" than north of it, the northern or rear portion was forced outward against the Hotel Patterson. This action is illustrated in Fig. 5.

As proof that the original break did not occur on the uppermost story, the unerected material and the derrick mast and boom were found on top of the mass of débris.

The structure collapsed because of lack of lateral support for the story columns, permitting them to act as continuous columns having a ratio of length to least radius of gyration in excess of the known limits for safety.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE LOCATION OF THE KNOXVILLE, LA FOLLETTE AND JELLICO RAILROAD, OF THE LOUISVILLE AND NASHVILLE SYSTEM.

Discussion.*

By Messrs. Emile Low, William P. Watson, E. J. Beard, Walter Watson, William G. Raymond, F. Lavis, W. H. Coverdale, Harvey Linton and W. T. Forsythe.

Emile Low, M. Am. Soc. C. E. (by letter).—The writer spent about nine years in the section of country adjacent to that traversed by the Knoxville, La Follette and Jellico Railroad, five years of which were in the service of the Norfolk and Western Railroad, and the other four years with the Mathieson Alkali Works, of Saltville, Va. Mr. Low.

In discussing Mr. Taylor's interesting paper, the writer desires especially to confine himself to a description of the Clinch Valley Division of the Norfolk and Western Railroad, with which he was very prominently identified.

During 1886, it was considered advantageous by the representatives of the Louisville and Nashville and the Norfolk and Western Railroads to enter into closer communication. Both systems controlled a considerable mileage of railroad, but were somewhat widely separated, the nearest points being Pineville, Ky., on the former, and Graham,

* This discussion (of the paper by W. D. Taylor, M. Am. Soc. C. E., printed in *Proceedings* for February, 1904), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to May 27th, 1904, will be published subsequently.

Mr. Low. Va., on the latter line, the distance separating them being about 200 miles.

The central point was in the vicinity of Big Stone Gap, Va., which was at first selected as the junction point. The junction was subsequently changed to Norton, Va.

As it was considered expedient to hasten the construction of the "missing link" with all possible speed, the authorities of the Norfolk and Western Railroad caused a hasty reconnaissance of their portion of the line to be made late in 1886. The report of this reconnaissance stated that apparently a very favorable line, as to grades and alignment, could be secured, the line after leaving Graham to follow the Bluestone River to its head, a distance of about 10 miles, with a maximum grade of 53 ft. per mile, then, crossing the divide near Springville, Va., to the Valley of the Clinch River, which was to be followed to the mouth of Guest River, a distance of about 90 miles, with maximum grades of 53 ft. per mile, then ascending Guest River, to Norton Va. (then known as Princes Flats), a further distance of about 20 miles, with maximum grades not exceeding those of other parts of the line. Shortly after the reconnaissance was made, several survey parties were placed in the field. One, starting at Graham, covered the eastern end of the line and, after reaching the Clinch River, kept to its north bank. This preliminary survey disclosed a decided peculiarity of the Clinch River, in the excessive sinuosity of the stream, which for long stretches formed a series of escalops. The same conditions existed at the western end, especially near the mouth of Guest River, and along the latter stream.

The section traversed by the Clinch Valley Division of the Norfolk and Western Railroad lies on the western slope of the Appalachians, which, in this region, are made up of many local ranges, the general trend of which is about S. 60° W. The Clinch River flows mainly between the Clinch Mountain on the south and Sandy Ridge and Cumberland Mountains on the north, the latter being also the general southern limits of the West Virginia and Eastern Kentucky coal fields. The railroad line just skirts the edge of these coal measures, which are reached by short branch lines.

It was at this particular stage that Mr. Taylor's Rule 4* came prominently into play. This rule reads:

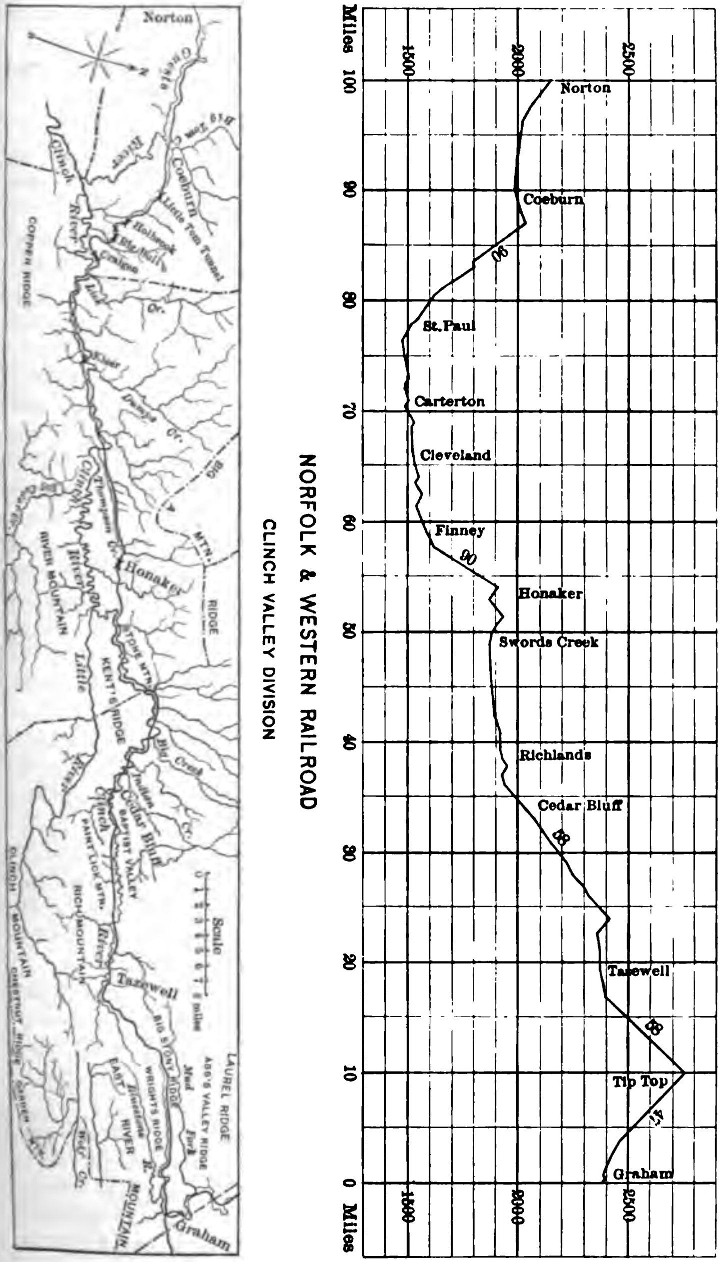
"(4) Of making a diligent study of the whole country, with a view of selecting a route with a minimum of adverse grade."

Owing to the extremely adverse topographical conditions in the valleys, it became absolutely imperative to seek for the most favorable ground, no extremely radical departure from the selected route being possible.

A new survey developed the existence of a somewhat lower summit

*_Proceedings_, Am. Soc. C. E., February, 1904, p. 136.

Mr. Low.



NORFOLK & WESTERN RAILROAD
CLINCH VALLEY DIVISION

Mr. Low. at the head of Wright Valley Creek, a tributary of Bluestone River, and the line was transferred to the valley of the former stream, a maximum non-compensating ascending grade of 47 ft. per mile having been adopted.

As at the head of the Bluestone River, the North Fork of the Clinch River heads against the source of Wright Valley Creek, and the line follows this fork to the main river, with a maximum compensated descending grade of 58 ft. per mile.

From the foot of this grade, the fall, for 6 miles, was comparatively light, being about 12 ft. per mile. The river then began to fall more rapidly, at the same time impinging upon the southern slope of the Baptist Valley Ridge and gradually cutting through this ridge and its continuation, Kent's Ridge, at Cedar Bluff, Va. An examination of the profile (Fig. 5) shows that the line leaves the Clinch River at Mile 22.5, passing over what is locally known as Young's Summit. Here occurs the first adverse grade (after passing Tip Top) in a generally descending grade of 66 miles. This diversion from the river was justified on account of the excessive cost of construction between Pisgah and Pounding Mill had the river been followed more closely.

Between Pounding Mill and Cedar Bluff, the Clinch River is extremely sinuous, the distance between two points by river being more than twice that in a straight line. As there was no possible alternate route here, the river was followed, entailing extremely heavy work. This section of the line is shown in detail in Fig. 6.

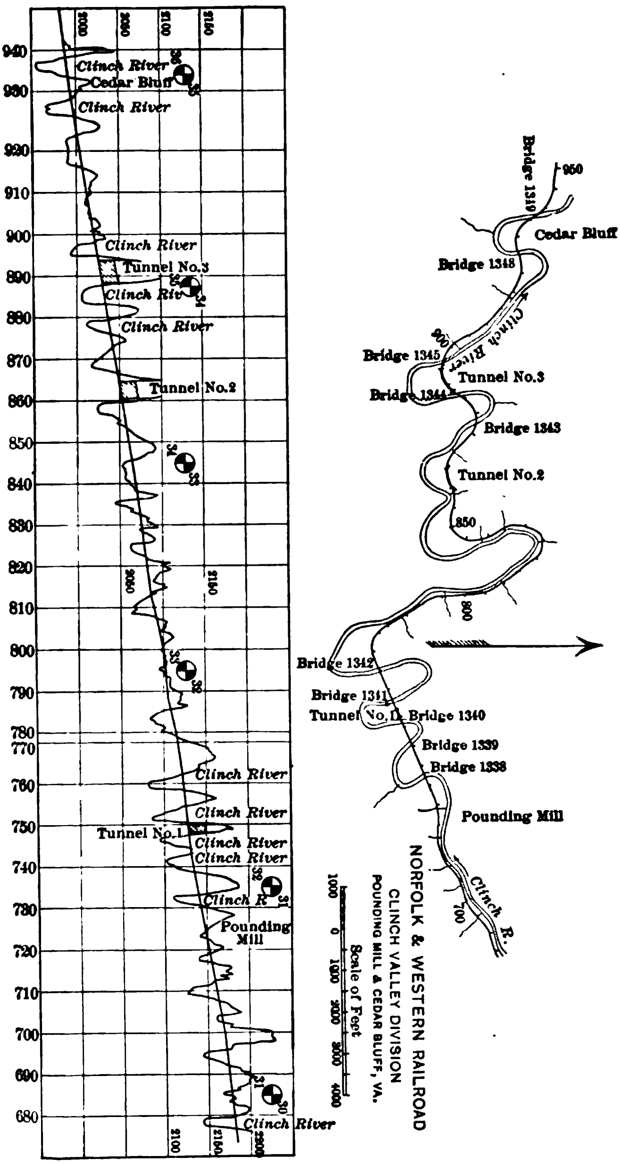
After leaving Cedar Bluff the fall of the river diminishes, being, for 15 miles, to Sword Creek, about 140 ft., or less than 10 ft. per mile. Although the course of the river is somewhat sinuous in places, there were no steep banks or bluffs. At Richlands there is one adverse grade, which could have been abolished at a comparatively slight cost.

It was the original intention, as previously stated, to follow the river between Sword Creek and the mouth of Thompson Creek, and the first survey was made on this course. An examination of the general map, however, will show the tortuous windings of the stream between the points named.

North of Honaker there is a high spur known locally as "Big A" Mountain, the slope of which is toward the south. Through the base of this mountain the river has cut its way, leaving on the south side a range, variously known as River Mountain and also as Elk Garden Ridge.

As the cost of the river line seemed prohibitive, an alternate line, involving less expense, was sought. It was found that a stream called Thompson Creek paralleled the river to the north for about 8 miles. The headwaters of this stream could also be reached from Sword Creek by a cross-country line, which utilized largely a branch of Lewis Creek.

Mr. Low.



Clinch River
Cedar Bluff
Tunnel No.3
Tunnel No.2
Tunnel No.1
Pounding Mill
Bridge 1349
Bridge 1348
Bridge 1345
Bridge 1344
Bridge 1343
Bridge 1342
Bridge 1341
Bridge 1340
Bridge 1339
Bridge 1338
Clinch River
Clinch R.
NORFOLK & WESTERN RAILROAD
CLINCH VALLEY DIVISION
POUNDING MILL & CEDAR BLUFF, VA.
Scale of Feet

Fig. 6.

Mr. Low. Surveys of this cut-off developed the fact that maximum grades of 53 ft. per mile could be obtained, but in order to secure them a tunnel 3 000 ft. long would be required. As this was considered too expensive a feature, the maximum grade was increased to 90 ft. per mile, the modification resulting in reducing the length of the tunnel to 900 ft. at the Honaker Divide. This change of line resulted in two adverse grades of 53 ft. per mile between Sword Creek and Honaker, and greatly increased the ruling grade to the eastward. From the mouth of Thompson Creek to St. Paul the line again followed the river. Between these places some adverse grades occur at points where the line cuts across large bends in the river, these grades having been adopted in order to minimize the excavation.

Perhaps the most difficult portion of the line was the location between St. Paul and Coeburn. The enormous expense of building a line up Guest River precluded this route at the beginning. Another cross-country line was then adopted. This line, as finally developed, left the valley of Clinch River, at Lick Creek, above St. Paul, gradually ascended the ridge forming the north bank of the river until the top was reached, near Creagan Tunnel, and then following Russell Creek, passing through Big and Little Bull Tunnels to the waters of Bull Run, all of which streams are tributaries of Clinch River. In order to reach the main valley of Bull Run the line passed through a spur by means of the Holbrook Tunnel. Another tunnel, Little Tom, occurred at the head of Bull Run and gave access to the waters of Little Tom Creek, a tributary of Guest River. The total elevation overcome was 556 ft. in a distance of 10 miles, corresponding to an average grade of 56 ft. per mile, although the maximum compensated grade used was 90 ft. per mile.

From Little Tom Tunnel the line descends to Coeburn, with a maximum grade of 30 ft. per mile, following the valley of Little Tom Creek, until Guest River is reached, which stream is then ascended to Norton, the maximum grade being 53 ft. per mile.

Referring again to the location between St. Paul and Little Tom Tunnel (near Coeburn), it may be stated that, in order to overcome the rise with a compensated grade of 53 ft. per mile, a grade line more than 11½ miles long would have been required, making necessary a development of 1½ miles or more. The foot of the grade could not well have been shifted to the east of St. Paul, as this is the proposed crossing of the Ohio River and Charleston Railroad (better known as the 3 C's Railroad), where a joint yard is proposed.

In order that the heavy nature of the work on this portion of the line may be more fully understood, a few of its characteristics are given in Table No. 1.

Not counting the smaller trestles, there are four high ones, approximating 150 ft. in height.

Mr. Low.

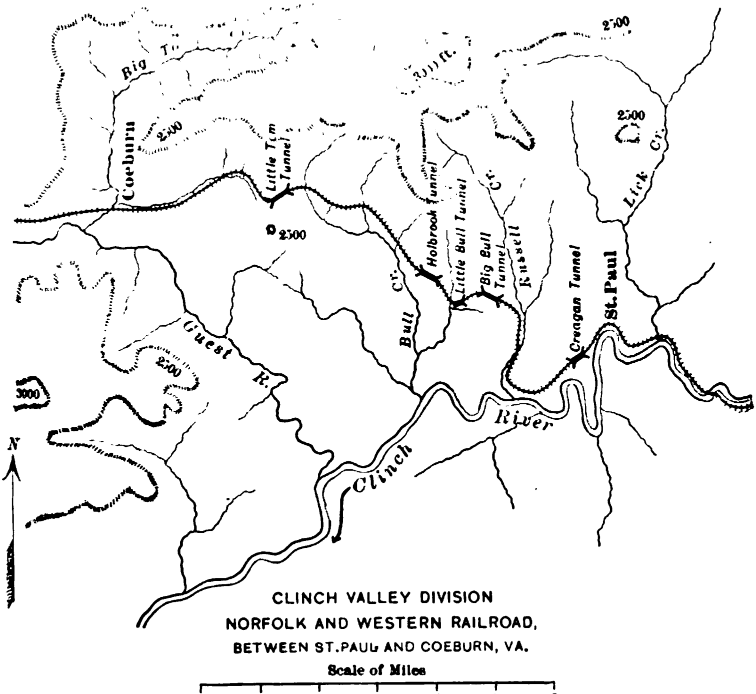


FIG. 7.

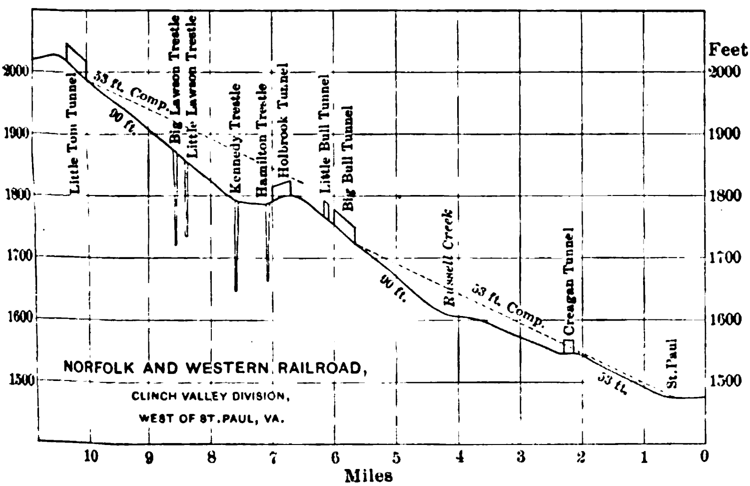


FIG. 8.

Mr. Low.

TABLE No. 1.

Name of tunnel.	Mile.	Elevation.	Length.
			Feet.
Creagan	79	1 547-1 547	905
Big Bull	82	1 725-1 754	1 695
Little Bull	82	1 761-1 766	827
Holbrook	83	1 801-1 992	1 566
Little Tom	87	1 989-2 022	1 925

To the initiated, an inspection of the profile west of St. Paul presents some vagaries, especially the two well-defined dips in a long ascending grade line. The first is caused by the crossing of Russell Creek, where the present crossing is 42 ft. high. A 53-ft. compensated grade would have made necessary a crossing 80 ft. high, and would have intersected the present grade line at the east end of Big Bull Tunnel; or, to intersect the present grade at the west portal would have required a development of about $\frac{1}{3}$ mile. This lighter grade, undoubtedly, would have increased the cost of construction between Creagan and Big Bull Tunnels, and the amount of traffic alone would determine whether such an additional outlay was justifiable.

Between Big Bull and Little Tom Tunnels, the situation is more serious. In order to introduce a compensated grade of 53 ft. per mile, there would have been required a development of 1 mile of line or a tunnel about 1 mile long at Little Tom Divide. The first would have increased the height of the high trestles to 200 ft., or more, and also would have added some other highly interesting engineering features. Had this railroad been constructed on a 53-ft. grade, it would unquestionably have been one of the most spectacular on this continent.

Before closing, the writer would like to add a few remarks in regard to the proper method of conducting railroad locations. It is the practice to cut up a proposed line of railroad into sections and allot one of these to each survey party. This is good as far as it goes, but the trouble is that each party is generally allowed to follow its own bent, in fact, to roam at its own sweet will, instead of filling in a part of a harmonious whole. Bad locations also result from improper organization, an insufficient number of members in the parties, delegating to the chiefs of parties such work as sitting up all night in a tent plotting the day's work, when such duties ought to be performed by draftsmen, especially provided for in suitable quarters, as well as in daylight.

With proper methods, surveys can be kept plotted up to date, and the locating engineer can thus have a broad view of the ground

he is covering, and also an intelligent idea of where to run additional lines, when needed to cover doubtful points. In addition, copies of all notes, including transit, level and topographical notes, should be sent (or mailed) to headquarters, at frequent intervals, to be worked up at once. Mr. Low.

This enables the chief engineer to see what is being done in the field, and also keeps him in close touch with all his assistants. Thus he can give such orders as to changes and improvements in the whole line as will result in producing a perfect design.

William P. Watson, M. Am. Soc. C. E. (by letter).—This paper has been read with much pleasure. The author is correct in the statement: Mr. W. P. Watson.

> "The economic questions which determined that the whole project of construction was advisable may be of more importance than the most intricate and learned calculation upon the strength or efficiency of special structural parts."

By the former, the economic success or failure of the enterprise as a whole is determined, while the failure of the latter affects, generally, only one part, and often a very small part, of the whole enterprise, and can be remedied easily by a more skilful and complete structure. For this reason, a skilful and scientific location of any given line of road is very rarely appreciated. As formerly stated, the work of the locating engineer may determine the success or failure of any given enterprise.

Of course, the determination to construct a line between two termini is the province of the executive branch of the road, but, even for this purpose, who can be a better adviser than the skilled engineer? After this has been determined, there come the minor economic questions of the selection of the route, wherein must be considered: First, the best route for traffic and the probable volume thereof; and secondly, the various questions as to the proper gradients, distance, rise and fall, and curvature, their degree of importance being in the order named. The first affects the revenue of the road, and the last four affect the yearly operating expenses, or the profits of the enterprise. They are as legitimate and proper subjects of consideration by the locating engineer as is the first cost of the construction; for they are taken care of by the annual operating expenses and the latter by the annual interest, or fixed charges; and yet what great sums are spent on railway construction without even considering any of these questions, except, probably, gradients. The writer has known chief engineers, who, after the ruling gradient had been decided upon (probably by the executive department, or management, from what it wanted and not from a scientific study of the subject), appeared to attach no importance to the other questions, indeed, had no thought or opinion upon them; and, when a comparison between any two lines was made, almost invariably took the line that showed the cheaper construction,

Mr. W. P. Watson.

no matter if obtained by almost any excess of distance, rise and fall, or curvature. And yet such men are entrusted with works of great magnitude, amounting to thousands and millions of dollars. It is only the abounding prosperity of the nation, and not the skill of the engineer, which, when such methods are allowed, makes an enterprise a success instead of a failure. It is therefore refreshing to see a location in which such questions have been considered.

The writer has given the paper only a hasty examination, but notes the following points:

Adverse Grade.—It would seem that the author has given an undue and disproportionate weight to the subject of adverse grades, and has fallen into the common error of adding up all the rises and falls, no matter how small, for any two compared lines, and giving the preference to the one having the greater aggregate total. This may be very fallacious, as that showing the lesser may have all its rises and falls in two or three long stretches of 10 000 ft. or more, and be very objectionable, while the other may have an undulating grade with numerous short rises and falls, of less than, say, 30 or 40 ft., so arranged that traffic can be handled as cheaply as on a level grade, upon the theory of "momentum or velocity grades" which is illustrated as follows:

Theory of Momentum or Velocity Grades.—A constant power (the locomotive) is applied to overcome the train resistance, then the undulations, or various rises and falls, are overcome by the momentum, or stored energy, which is increased, or stored up, on the descents and

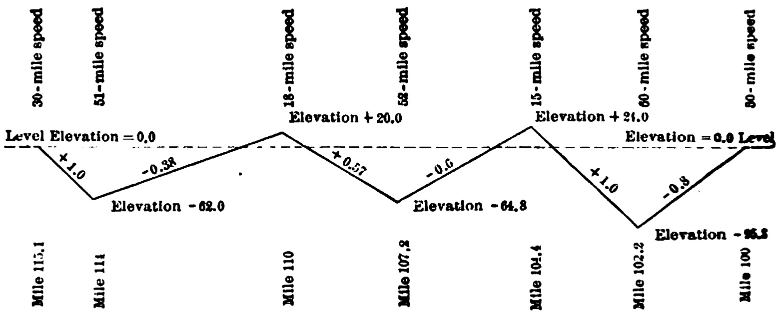


FIG. 9.

given off on the ascents, as illustrated in Fig. 9. This is what engine men mean by the expression "taking a run at a hill."

Fig. 9 represents the profile of an imaginary line whereon a locomotive is supposed to be able to haul a train on a level grade at 30 miles per hour and to exert the same tension upon the draw-bars up and down hill, the alignment being arranged so as to allow of very fast

speeds. The calculation of the different speeds is illustrated in Table No. 2. Mr. W. P. Watson.

A train in motion at 30 miles per hour has a potential lift of 32 ft., vertically.

TABLE No. 2.

Mile.	Elevation (or lift), in feet.	Difference in elevation of sags and summits, to be added or subtracted.	Equivalent lift, in feet.	Equivalent speed, in miles per hour.
100.........	0 (It is assumed that at Mile 100 the train has a speed of 30 miles per hour)			30
102.2.......	95.8	+ 32*	127.8	60
104.4.......	127.8 (lift due to 60 mile speed)	− (95.8 + 24)	8.0	15
107.2.......	8.0 (lift due to 15-mile speed)	+ 24.0 + 64.8	96.8	52
110.........	96.8 (lift due to 52-mile speed)	− (64.8 + 20.0)	12.0	18
114.........	12.0 (lift due to 18-mile speed)	+ 20.0 + 62.0	94.0	51 +
115.1.......	94.0 (lift due to 51-mile speed)	− (62.0)	32.0	30

*Original potential lift, due to a speed of 30 miles per hour.

Thus the table shows that at Mile 115.1 the speed is 30 miles per hour, or the original starting velocity.

Is it not evident that a road constructed on such a profile can be worked as cheaply as an equivalent level road (except for the practically unmeasurable wear and tear on track and rolling stock due to varying speeds), and with actually no more application of power, provided the velocities can be maintained safely?

The writer would not advise carrying this to the extent suggested by Wellington, that is, using grades greater than the maximum, in these sags and rises, for, although this is correct, theoretically, it pre-supposes always an unobstructed track. While this may generally be so, it may not always. Suppose the grades on each side of the sag at Mile 102.2 were beyond the maximum. Is it not apparent that any obstruction necessitating a stop then would stall the train and impede, or tie up, the traffic for the entire division, invalidating all its fine-spun theories and elaborate calculations? A slippery rail near the summit might have the same effect, for, though this might not interfere with the potential lift, it would interfere with the constant force, the locomotive, because, with freights especially, the ability to start a given load up any grade limits the amount of that load, and, if it were not for the elasticity in the springs of the couplers, it is doubtful whether an engine could start a load which it could readily pull.

This would indicate that these sags could be made 80 or 90 ft., but the line must be located for its weakest member, which would be a

Mr. W. P. Watson. freight of 40 or 50 cars, with speeds of from 15 to 30, or 25 to 40, miles per hour.

With speeds of from 15 to 30 miles per hour the safe sag would be

$$(3.0^2 \times 3.55) - (1.5^2 \times 3.55) = 24 \text{ ft.}$$

With speeds of from 25 to 40 miles per hour, the safe sag would be

$$(4.0^2 \times 3.55) - (2.5^2 \times 3\ 55) = 35 \text{ ft.}$$

Therefore, a line located with an undulating grade, containing sags not exceeding 30 ft., or on special occasions 40 ft., would be within safe limits, provided the ruling grade were not exceeded.

The foregoing calculations are dependent on the ability to maintain fast speeds. Therefore, anything which would interfere with this should be avoided. A sharp curve at the bottom of a sag, say at Mile 102.2 in Fig. 9, would not be permissible. Such a curve half way down would not be as objectionable, or could be introduced at a summit without harm, if properly compensated.

Distance.—The author has hardly given due weight to the question of distance, and the writer is not sure that the advantages attained are sufficient to compensate for the lengthening of the line about 11 miles more than that of the Southern. The operation of an increased distance of this extent will probably cost an additional 50 cents per train-mile. The cost for 10 trains daily each way, at $1.08 per train-mile (the cost on the Louisville and Nashville System), is calculated as follows:

50 × 365 × $1.08 × 2 × 10 trains = $4 042 per year added to general operating expenses for one train-mile, and, for 11 miles, this makes $44 462, which, capitalized at 4% per year, gives $1 111 550.

Thus it would be justifiable to expend on first construction more than $1 000 000 to save this distance.

Now, from an examination of Fig. 2, it looks as if this excess distance was lost between Knoxville and La Follette, and it also appears that a 1% line could be obtained. Suppose such a line to have been located, following, in the main, the Southern from Knoxville to the Clinch, then, which seems to be the natural route, up the Clinch to Big Creek and up latter to La Follette. It is generally cheaper and better to keep the railroad line as near the natural drainage ways as practicable. This would also have had the advantages of opening a new and unoccupied territory. The selection of the line through La Follette and from there to Jellico seems to have been eminently wise and correct.

This supposed line between Knoxville and the Clinch would have about the same rises and falls as the Southern, the extreme elevation of any point being about the same as that of the Knoxville, La Follette and Jellico Railroad between the same points. But the former has the additional rise and fall, out of and into the valleys of Beaver and

Mr. W. P. Watson.

Bull Run Creeks, which amount to about 125 ft. for the former and 225 ft. for the latter, or a total of about 350 ft. Now, in continuous stretches of 100 ft. and more such rises and falls add to the yearly operating expenses $1.85 per foot of rise and fall per train-mile, or, for this line, with the assumption of 10 trains per day, each way, and $1.08 per train-mile, this would be

$$\$1.85 \times 10 \times 2 \times 1.08 = \$39.96,$$

which, capitalized at 4% per year = $999. That is, it would be justifiable to spend about $1 000 per foot to eliminate the rises and falls. The comparison, with the increase in yearly operating expenses, for the two items of distance and rise and fall, capitalized, is as follows:

The Present Knoxville, La Follette and Jellico Railroad Location.

To 10* miles distance (increased) at $100 000 per mile	$1 000 000
First cost of excess 10 miles, say $60 000	600 000
Total excess of present location	$1 600 000

Supposed Location.

To 350 ft. of rise and fall at $1 000	350 000
Total in favor of supposed location	$1 250 000

This is upon a 1% (or 53 ft. per mile) ruling gradient.

But the present location is adapted for a ruling gradient of 35 ft. per mile on all south-bound traffic, and the cost of putting this supposed line upon this basis should be deducted. Now, it seems highly probable that by constructing heavy tunnels, say two, 4 000 ft. long, through the summits of Copper and Chestnut Ridges, this could be accomplished. It would look as if it would be better to have a helper for the Bull Run Valley, the grade for which could be 1.55%, or 82 ft. per mile, two engines hauling upon this what one would haul on a 0.65% grade. One engine would be sufficient, as the distance would be only 4 miles, and only south-bound trains would have to be helped. Again, probably 5 miles of extra line would have to be built for the Oliver Springs Branch, and would probably cost $30 000 per mile. There would also be two larger tunnels. The helper engine and the 1.55% grade would probably bring the question of rise and fall under the rule of momentum grades, and eliminate the question from the comparison entirely. The mile of distance allowed for development

* Only 10 miles' increase is charged, as 1 mile may be lost in developing the supposed line to a 1% grade.

Mr. W. P. Watson.

would be reduced probably as much as ½ mile. The statement would then compare about as follows:

To excess cost of present location (as before)			$1 250 000
For reducing the proposed 1% line to a 65% line for south-bound business:			
2 tunnels (8 000 ft.) at $100		$800 000	
1 helper service (the author's cost is assumed for this, though it is thought to be high)		350 000	
Branch to Oliver Springs, 5 miles at $30 000.		150 000	
		$1 300 000	
But from this is to be deducted the following:			
350 ft. of rise and fall saved, at $1 000	$350 000		
½ mile of distance, including cost of construction	80 000		
		430 000	
			870 000
Balance in favor of the proposed line			$380 000

If such a change could have been made, on the foregoing basis, it should have been done, as this is bound to be a link in the main line, and subject to severe competition. There is also the probability of the traffic increasing, thus making the comparison continually more favorable than that given.

Of course, the foregoing is merely a supposititious case, and might be wholly impractical of realization in the field, but, at least, it shows the danger of ignoring such an important economic question as 11 miles of increased distance.

Ruling Gradient.—In the author's treatment of this point he is slightly in error. In the first place, it is improper to assume that trains are not fully loaded, for it is the duty of the management to see that the power is used, up to its full safe capacity, thus obtaining the greatest economy. If the grades or traffic in one direction are different from those of the other, as they are, almost always, this must be made up by the size or number of trains.

Secondly, while operating expenses may vary directly as the train-mileage, they do not vary as the number of trains. This is shown in Table No. 3.

TABLE No. 3.—ESTIMATED PROBABLE COST OF DOUBLING THE ENGINE TONNAGE TO HANDLE THE SAME TRAFFIC, UPON 1 MILE OF RAILROAD, DUE SOLELY TO AN INCREASE IN THE MAXIMUM OR RULING GRADIENT. Mr. W. P. Watson.

Subdivisions.	Percentage.		Added Cost.	
		Affected.	Details.	Total.
Maintenance of Way and Structures.				
Repairs of roadway	0.11732	80	0.09386	
Renewals of rails	0.02581	80	0.02065	
Renewals of ties	0.04154	80	0.03323	
Repairs to bridges and culverts	0.02000	80	0.01600	
Repairs and renewals of fences, road crossings, signs and cattle guards	0.00757	....	....	
Repairs and renewals of buildings and fixtures	0.01582	....	....	
Repairs and renewals of docks and wharves	0.00005	....	....	
Repairs and renewals of telegraph	0.00261	....	....	
Stationery and printing	0.00011	....	....	
Other expenses	0.00092	....	....	
Totals	0.23175	....	....	0.16374
Maintenance of Equipment.				
Superintendence	0.00766	....	....	
Repairs and renewals of locomotives	0.07372	90	0.06635	
Repairs and renewals of passenger cars	0.02318	05	0.00116	
Repairs and renewals of freight cars	0.05718	10	0.00572	
Repairs and renewals of work cars	0.00248	....	....	
Repairs and renewals of shop machinery and tools	0.01040	....	....	
Stationery and printing	0.00036	....	....	
Other expenses	0.00396	....	....	
Totals	0.17896	....	....	0.07323
Conducting Transportation.				
Superintendence	0.00700	....	....	
Engine and round-house men	0.09375	80	0.07500	
Fuel for locomotives	0.09337	75	0.07003	
Water supply for locomotives	0.00873	70	0.00611	
Oil, tallow and waste for locomotives	0.00429	70	0.00300	
Other supplies	0.00125	70	0.00087	
Train service	0.06545	80	0.05236	
Train supplies and expenses	0.01609	80	0.01287	
Switchmen, flagmen and watchmen	0.03070	50	0.01535	
Telegraph expenses	0.02341	....	....	
Station service	0.06902	....	....	
Station supplies	0.00847	....	....	
Car-mileage balance	0.04516	....	....	
Loss and damage	0.01250	....	....	
Injuries to persons	0.00743	....	....	
Advertising	0.00878	....	....	
Outside agencies	0.02840	....	....	
Commissions	0.00048	....	....	
Rents of buildings and other property	0.00126	....	....	
Stationery and printing	0.00456	....	....	
Other expenses	0.04010	....	....	
Totals	0.56020	....	....	0.23559
General Expenses.				
Salaries of general officers, insurance, law, etc.	0.02909	....	....	....
Estimating the extra engine to cost $12 500, and capitalizing at 4% per annum, the interest charges would be $500; and estimating the daily engine run to be 110 miles, or 40 000 miles per annum, the cost per mile is	....	....	....	0.01250
Total	....	....	....	0.48506

Mr. W. P. Watson.

Thirdly, it seems to the writer that $2 900 000, the result of the author's calculation for the saving by the change in the ruling gradient, is fully one-half too large, and that the method shown in Table No. 3, which is practically Wellington's method, is the better. The writer has taken the annual operating sheet of the Missouri Pacific Railway for 1902, which will serve as a standard, and has reduced the various items to percentages, the gross total being unity.

The value or percentage in Table No. 3 ($0.48806) is for one train one way, but if a change is made in the maximum, or ruling, gradient, it affects the load on the entire division, which, for convenience, may be called 100 miles long.

Therefore, to double the engine-tonnage to haul the same traffic, due solely to a change in the ruling gradient, on a division 100 miles long, will cost $48.806 per 100 train-miles per day, or $48.806 × 365 = $17 894.20 per annum; or, as the train-mile on the Louisville and Nashville costs $1.08, this will be $17 894.20 × 1.08 = $19 325.70 for increase of 1 engine-mile, or 100% per year per daily train one way only.

Now, an engine will pull 73% as much on a 1% grade as upon a 0.65% grade, or, to haul as much, will increase its mileage. $\frac{1.00 - 0.73}{0.73} = 0.369$ per cent. But an increase of 1 engine-mile, or 100% per year per daily train for a 100-mile division, is $19 325.70, and for a 79-mile division and 10 trains daily, one way only, this change will be worth $19 325.70 × 0.369 × 0.79 × 10 = $55 511 saving in the operating expenses, which, capitalized at 4% per annum, gives a capitalized saving of $1 387 775 by changing the ruling gradient from 1% to 0.65 per cent. But even this saving would fully warrant the change, which, therefore, was a wise and proper one.

It is manifest from an examination of Table No. 3, showing the operating expenses of the Missouri Pacific Railway, that there are many items therein which are not affected by an increased train service, as, for instance, general expenses, superintendence, etc., etc.

Vertical Curves.—For a link in a main line, when fast speeds are desired and expected, a gradation of 0.05 ft. per station (100 ft.) in sags and 0.10 ft. at summits makes a better and more easy transition than those mentioned by the author. Some recommend even a flatter curvature, but, with the present general use of springs in couplers, 0.05 and 0.10 ft. are sufficient.

Transition Spirals.—A spiral increasing 1° in 60 ft. is too short for a line of this character, as it is suitable only for a speed of about 36 miles per hour.

The writer believes that very seldom has a line received such thought and study regarding the main questions of location—the eco-

nomic questions—and the author deserves great credit for laying it before the Society so fully. The writer regrets that time prevents him from going into the subject more thoroughly. Mr. W. P. Watson.

E. J. Beard, M. Am. Soc. C. E. (by letter).—This paper is dedicated primarily to the young and inexperienced, and, therefore, it is important to call attention to some statements and computations wherein the author, in setting forth some of the considerations which determined important steps, has evidently committed errors, the pointing out of which, it is hoped, will prevent some of the dedicatees from falling into the same mistake. Mr. Beard.

It is not true, as the author states and applies, that the "operating expenses vary directly as the train-mileage," for only a part of the total operating expenses is affected by the addition or deduction of one or more trains. It is not necessary to enter into history to verify this statement, as all railroad engineers (and, for that matter, all operating officials) should be thoroughly familiar with the principles underlying, and so admirably set forth in, the work of the late A. M. Wellington, M. Am. Soc. C. E. While the percentage cost of each item of expense to the cost of a train-mile, as contained in Wellington's "Economic Location," is not strictly correct at this date (due to change in conditions), his tabulations can be quickly brought up to date by the application to them of the data found in detail in the reports of the various State Railway Commissioners, the annual reports of various railroads, or, sufficient for all practical purposes, from the work quoted by the author.*

Wellington states that some 50% of the cost per train-mile is affected by an increase or decrease in the number of trains. While there is some variation, under ordinary conditions, in the cost of each item since Wellington wrote, his figure, 50%, is not, at this date, very far wrong when the change (*i. e.*, the increase or reduction in train-miles) is considerable, but when such a small reduction in the number of trains is accomplished, as by the author on the road in question, it is doubtful if the change would amount to more than 35 or 40% of the average cost ($1.08) per train-mile on the Louisville and Nashville Railroad.

The statement that he is conservative in adopting this cost per train-mile, and in justifying the statement by referring to the cost per train-mile on the Duluth and Iron Range and the Duluth, Mesaba and Northern Railroads, is hardly to be considered true after looking into the operating conditions shown by the statistics of these roads, coupled with a belief in the very different operating conditions of each. From the United States Statistics of Railways, before referred to, the percentage cost per train-mile of the four grand divisions, referred to the total cost of a train-mile, is as shown in Table No. 4.

* "Statistics of Railways in the United States," compiled by the Interstate Commerce Commission.

Mr. Beard.

TABLE No. 4.

	L. & N.	D. & I. R.	D., M. & N.
	Percentage.	Percentage.	Percentage.
Maintenance of way	21	27	35
Equipment	22	27	25
Transportation	52	42	34
General	5	4	6
Totals	100	100	100

This table shows that the excessive cost of maintenance of way and equipment (notably the former), compared with that of transportation, is excessive as compared with that shown for the Louisville and Nashville. Although the writer is unfamiliar with any of the roads named, it would seem evident that climatic and other conditions on the Michigan roads, compared with those on the Louisville and Nashville, are the cause. There is nothing in the paper to indicate excessive maintenance expense, and, no doubt, it will at least average with that of the system of which it is a part, which, it is ventured to say, varies little, mile for mile, in the items of expense affected by trains or engine, when the number of trains is equal.

There are seemingly several reasons why the average train-mile cost on the road in question, if it had been built on a 1% maximum, should not be any higher than the general average of the Louisville and Nashville. One is that there are many items included in the cost per train-mile (which is merely the unit of the grand total of the operating expenses of a great system, and includes many items, such as general officers, general office forces and other expenses), which will not in any wise be affected by the addition of this small mileage to the total of the road. In other words, it is not reasonable to assume that, when the cost of operation per train-mile on 3 000 miles of road is $1.08, the addition of 79 miles, over which is to pass the same average train-tonnage per annum, will increase the annual operating expenses by the annual train-miles on 79 miles at $1.08 per train-mile. What has been said indicates the wide reasoning necessary to be conservative, and to be so that something less than $1.08 would be likely to be in order. However, to show more fully the wrong results arrived at by the author, that figure will be used later.

The author states that it was "in no wise certain that the 1% grade would be used as a helper grade." How, then, is he justified in recommending the expense of reducing the other two 1% grades to 0.65 per cent? The truth, no doubt, is that, whatever the number of trains, they will (as far as it is safe for the engineer to go) practically all arrive at the foot of the hill loaded to require a helper, as the

operating department will hold for full train loads, unless the unbalancing of traffic should occasionally require return of power to the other end—an exigency unsafe to figure on—and the only proper thing to do is to figure on pushing all the trains estimated to be required for the traffic to be handled. Again, why run the helper engine 4 miles more than the length of the helper hill? It should not, and is not likely to, be done, as it would give 16 or 17 miles, say (with properly located sidings), as the length of the helper's round trip, instead of 24 miles and for 8 trains per day, or, with half that number on Sundays, 46 104 engine-miles per annum. The author also wrongly states that 4 trains on the 0.65% grade will handle the same tonnage as 6 trains on the 1% grade, representing a decrease of 33⅓% in engine- or train- mileage, when the relation between the grades in this respect is a reduction of 27 per cent. While this is true, probably a reduction to 8 trains should be estimated on instead of the exact ratio, 7.3. Mr. Beard.

From the foregoing data is obtained the annual saving in operating expenses due to the reduction in the number of trains, as follows:

20% of 20 trains (10 each way per day) × 35% of $1.08 × 79 miles × 39 days per year = $10 492.87.

This sum, capitalized at 4%, gives but $1 012 322, a sum vastly less than that arrived at by the author.

In determining the effect the operation of the helper engine will have on transportation, maintenance of way, and equipment expenses, it would have been better to have obtained the data from the statistics of the Louisville and Nashville instead of taking those of the Pennsylvania Company, where conditions of operation are distinctly different, and adaptable to but few roads in this country. In lieu of nothing better than the "Statistics of Railways," those can be used, which, no doubt, conform closely enough for the purpose to the conditions that would be encountered. Obtaining therefrom the following, as the percentage per train-mile of operating items affected for maintenance, equipment and transportation (except wages) gives:

Repairs and renewals of locomotives....	7.3	per cent.
Superintendence and general expenses..	0.6	"
Fuel..................................	10.8	"
Water..................................	0.65	"
Oil and waste..........................	0.35	"
Other supplies.........................	0.2	"
Telegraphing and despatching..........	1.1	"
Total..............................	21.0	per cent.

It is no doubt true that the expense of these items, in the case of a helper engine, would vary somewhat from the general average

Mr. Beard. of a road engine of the same pattern, but, in view of the severe and erratic service required of the helper, it would probably be more than for a road engine.

The assumption that half of the maintenance-of-way expenses is due to engines alone is, to say the least, a crude method, if one stops to think of how the introduction of a helper would affect in any manner whatever most of the items making up the total of such expenses, except as to roadway, rails and ties. Probably something like one-half of that proportion of the rail wear due to trains is due tothe engines alone, but that ratio does not, as assumed by the author, apply to any of the other items, and the most that can be charged to maintetenance of way is something like the following:

Renewals of rails	1 cent,
Repairs to roadway	3 cents,
Ties	0.6 cent,
Switches and sidings	0.4 "
Miscellaneous	1 "
Total	6.0 cents,

or about one-half the author's estimate. The coincidence of the total of transportation, and maintenance of way and equipment about equalling the author's, of course, has no meaning. His erroneous reasoning would give an error of $\pm$ 25 cents per train-mile, or about 50% in such a case as the Duluth, Mesaba and Northern. Summing up these items gives, as the annual cost of one double-crewed helper engine, the following:

Interest on $14 000, cost of helper engine, at 4 per cent	$560
Annual wages of crew	3 744
46 104 train-miles at 27 cents	12 448
Total	$16 752

This is somewhat nearer the annual cost of a helper engine, which, by the writer, is almost invariably estimated at $18 000 per annum, and, in view of the many non-estimable objections to the use of a helper, is none too large. To draw attention to what some of these non-estimable objections might consist of, take this 8-mile helper hill. It will be found in practice that 8 freight trains per day each way is about the limit of one helper's capacity on such a hill, and its use will tend to delay trains at the foot of the grade, delay meetings at other places, and generally interfere with the even operation of the road, in comparison with what it would be if no helper were required. All these delays mean expense—fuel, wages and other concomitant items

—and probably $20 000 would not be too high to estimate as the annual cost of this pusher; but this is not intended to decry the use of pushers. From these figures, the estimated cost of change, to lower the ruling grade, would be as follows: Mr. Beard.

Annual cost of a helper engine on the Cumberland-Clinch Divide, $18 000 capitalized at 4 per cent..............................	$450 000
Construction cost of two tunnels.....	195 180
Interest on construction for one year, having no earning power during the construction of tunnels..................................	140 000
Total cost of change to lower grade.....	$785 180

There are other increased expenses, due to a reduction in ruling grade, to add to this. One, often overlooked in estimating the saving in operating cost accomplished by the reduction in train-miles for the same tonnage traffic obtained by the reduction of ruling grades, is that this reduction increases the cost of operation per train over every grade plane the rate of which is less than the ruling grade. Stated in another way, the value of a foot of rise and fall varies with the ruling grade. An engine loaded for the higher ruling grade can proceed on any less grade at a speed equal to that attainable if loaded for the lower ruling grade, with the consumption of less fuel; or, in another way, like engines will require and consume more time over a given division after its ruling grades are reduced to a lower maximum than before the change, when loaded for the respective ruling grade, resulting in increased expense for all items affected by time. The result of disregarding this fact is that often the advantages and saving in operating expenses estimated on by the engineers are not realized, and, consequently, the expected decrease in cost per ton-mile is not realized, the operating department finding it necessary to decrease the engine rating below that indicated by the differences in ruling grades, in order to get trains over the division within reasonable time and with economy. Take the line under discussion: It will require from 15 to 20% more time for a train, having an engine loaded for a 0.65% maximum grade, to go from Saxton to Knoxville than it would for the same engine loaded for a 1% grade. This, probably, would not affect train wages, in view of the shortness of the division, if operated as one division; and whether or not it is to be operated that way is understood as yet to be unsettled. But, no matter how it is operated, time affects fuel, water, oil, etc., all of which will be increased from 15 to 20%, and some other items not necessary to enter into here to affect the reasoning. If the cost of fuel, oil and water is, as has been assumed, 11.8%, this gives an expense here (due to this condition)

Mr. Beard. of 20% of 11.8% of \$1.08 × 16 trains × 79 miles × 339 working days = \$10 922.

\$10 922, capitalized at 4%, gives............	\$273 038
Increased cost (before obtained).............	785 180
Total..............................	\$1 058 218

This amount wipes out entirely the saving expected by the reduction of ruling grade. While but an approximation, this is not far from the truth, and, without a doubt, the President of the Louisville and Nashville Railroad certainly does not yet understand.

It will not be amiss to warn the inexperienced not to take literally all the author's remarks about smoothness of grade lines, by which he awkwardly expresses absence of rise and fall, which, though an important matter, is minor to that of ruling grades. Its value is readily estimated, and, to avoid a few feet more or less on minor grades, will not warrant a very great expense. Neither should he take literally the implication that it is easier to obtain the best across Missouri's northwest prairies than through Tennessee's mountains. Many who have had experience in both kinds of country will bear out the remark that the contrary is true. Titanic work is not the embodiment of good engineering, and the 40% more rise and fall on the Missouri road, considered with the conditions of years ago under which it was built, together with its cost (perhaps \$15 000 to \$20 000 per mile, at present prices), as against \$69 000 per mile for the Tennessee road, does not, by any means, indicate better engineering on the latter. The elimination of the 10 or 11 ft. more rise and fall per mile would not warrant, with like traffic, an additional expenditure exceeding probably \$2 000 per mile, giving a cost of from \$17 000 to \$22 000 per mile, as against \$69 000. An examination of a map of the country crossed by the Chicago-Kansas City lines shows their general direction to be across the drainage, and each valley is from 250 to 350 ft. below the saddles of the ridges, thus approaching those of the author's road.

Mr. W. Watson. WALTER WATSON, Assoc. M. Am. Soc. C. E. (by letter).—While the general rules to be followed in making a location given by Mr. Taylor* are vital and quite full, the writer would extend them somewhat by making the first one read:

(1) Of not using at any point more difficult gradients, nor any greater distance, nor any more curvature, nor stiffer curves than the country actually requires.

The writer would also suggest the desirability of adding another rule, *viz.*:

(5) Of occupying, at all strategic points, as fully as possible (without otherwise injuring the location), all the available ground.

* *Proceedings*, Am. Soc. C. E., February, 1904, p. 136.

Many engineers do not fully appreciate the value of distance and curvature saved, nor do some seem to appreciate the fact that it is not always the line that shows the least construction cost per mile that is the cheapest, even to construct. As an illustration of the effect of distance and curvature the following experience is cited: Mr. W. Watson.

The writer recently had occasion to revise a projected location, made previous to his engagement, through a very crooked valley with high bluffs on each side. These bluffs placed seemingly insurmountable obstacles in the way of any location, except one which followed the general windings of the valley, and, even then, quite heavy work was required. At one place, covering about 1½ miles of the original location, it was found, however, that by introducing two tunnels (of about 550 and 260 ft. in length) a line could be located, with the same gradient, with lighter curves, with about 320° less curvature and about 2 170 ft. shorter. Although the construction of the new line was more expensive per mile, it was actually about $9 000 cheaper than a line on the original location would have been, besides being much less expensive to operate.

Without in any way seeming to criticise the location shown on Plate III,* for which it is presumed there were most excellent reasons, the writer would like to ask if it was on account of lack of sustaining ground from the Bull Run side of Copper Ridge toward Lee's Ford (territory outside of the limits of the plan on Plate III), that the long detour around Copper Ridge was used, rather than a line up Beaver Creek from Open Valley, near the point *P*, and then passing directly under Copper Ridge by a tunnel to the Bull Run slope of the ridge, or whether there were other considerations entering into the problem? Plate III would indicate that possibly such a line, with the same rise and fall and gradient as the line located, and from 1½ to 2 miles shorter, but requiring an indicated tunnel about 2 500 ft. long, compared with one 2 170 ft. long on the line as located, might have been used, provided suitable sustaining ground could have been obtained toward Lee's Ford.

In regard to the suggested rule (5), it may be stated that there are often cases in difficult country where the line can be properly located, so that it would be extremely difficult for a rival company to construct a line through the same pass or valley, while a location, equally good in other respects, could be made, which would leave room for a rival to pass, and thus the situation would not be fully controlled. The complete control of such a pass, or valley, might add very materially to the value of the property.

William G. Raymond, M. Am. Soc. C. E. (by letter).—This paper is of the greatest interest to all those having to do with railroad location. There are one or two points that will perhaps bear emphasis. The first Mr. Raymond.

* *Proceedings*, Am. Soc. C. E., for February, 1904.

Mr. Raymond. is the great value of the topographic charts of the United States Geological Survey. Time and again have these charts been used in projecting water-supply work. Time and again have they revealed reservoir sites and conduit routes which would have been entirely missed by the reconnoitering engineer. And, for the use of the railroad locating engineer, they are even more valuable, not only saving his time, but insuring, with the exercise of reasonable care and intelligence, the selection of the most feasible route between two termini by compelling the following of Wellington's precept, stated anew by Professor Taylor in his fourth emphatic suggestion, that the reconnaissance shall be of an area, not a line, and by furnishing a small-scale, bird's-eye view of the widest possible area in such way that it may all be taken in at a glance, all seen at once, and be all at once before the engineer for study. The writer has used these charts for both railroad location and water-supply work, and has found them invaluable aids. The completion of the charting of the entire country cannot be accomplished too soon.

A second point is that the low grade line does not always mean the most expensive line even in first cost; that, in general, an economical location is one which adopts the lowest possible grades for the longest possible distances, and bunches the difficulties at a few points where they may be overcome most economically by heavy work or by pusher service.

A third point is the evidence furnished by this paper of the advance of railroad location from a trade to a profession; from the "rule-of-thumb" methods of many years ago to the scientific methods of to-day. And this without reflecting on those great men who, early in the history of railroad building, saw the true relation between location and operation. Moreover, the paper emphasizes the necessity for taking time and spending money in the design of the road, and by design is meant location, and for doing the work over, revising and re-revising, until the best that can be done by the united efforts of all the engineering talent engaged has been accomplished.

One suggestion: The paper professes to be written for the young men. Therefore, from the teacher's standpoint, should not the qualifying adjective "capitalized" be used before "cost" in the second paragraph on page 138?*

One other suggestion: In determining the cost of pusher-engine service, only those items of expense which may be attributed to this particular service are used, a proceeding that seems rational; but, when it comes to a consideration of the saving due to the reduction in train-miles by the lower ruling grade, it is stated that "operating expenses vary directly as the train-mileage," the cost per train-mile on the Louisville and Nashville Railroad for the year 1902 is used in the

*Proceedings, Am. Soc. C. E., for February, 1904.

following calculation, and the total saving is found by multiplying the train-miles saved by this train-mile cost, $1.08. This, being the average cost of all trains, is, of course, as the author points out, not the proper cost to apply to the heavy freight trains, the ones affected by the grade changes considered, but is used for safety, the actual cost of trains not yet running being indeterminate. The author estimates that the average train-mile cost of these heavy trains may be as great as $1.50; but, whatever it is, will the saving in money, due to a saving of train-miles, equal the cost per train-mile multiplied by the train-miles saved? Manifestly, it will not, and a considerable part of the late Mr. Wellington's great work was devoted to showing that it will not be this quantity. Railroad bookkeeping may make it so appear, and an increased number of trains due to increased business does not always seem to lessen the train-mile cost, as it should, theoretically, but this is due largely to increased expenses warranted by the increased business, and is not at all due to the greater number of trains. In recent years train-mile cost has increased greatly, but this is not due to the running of more trains. When the business does not change, and a reduction in train-miles, due to a reduction in grades, or increased locomotive power, is secured, it is doubtful if more than half the average train-mile cost is saved for each train-mile saved. Just how much the saving is, no one knows. In the present case, if $1.50 per train-mile is a fair cost for the trains affected, and half of this can be saved with each train-mile saved, the annual saving will be $80 343, instead of $116 000, and the amount gained by the changed line will be $1 327 420, instead of $2 218 845. The reduction of nearly $900 000 in the capitalized saving in no wise changes the correctness of the final choice in this case, but it might well change it in some other case where the difference in values might not be so great. With an assumed train-mile cost of $1.50, it is entirely possible that each train-mile saved may mean $1.08 saved, but the evident purpose of the author was to use the whole train-mile cost, making only as much allowance as would insure his being within that cost. Mr. Raymond.

Whether or not the suggestion here made is wise, may be a matter of opinion; it outlines the procedure the writer would follow.

With this change, and possibly without it, the paper seems to be one of the most valuable that has recently appeared for the study of the young engineer.

F. Lavis, Assoc. M. Am. Soc. C. E.—The speaker thinks that it was unnecessary to offer any apology for the presentation of this paper on account of the fact that the perusal of it might be loss of time to some experienced engineers. An engineer who is interested in railroad location as a science cannot fail to be interested in the development of such a low grade line through a very rough piece of country. The speaker does not feel sure that the low grade was warranted, but will refer to that later. Mr. Lavis.

Mr. Lavis. The literature on the practical aspects of railroad location is chiefly conspicuous by its absence, and a description of this kind, of actual work performed, is therefore valuable. It would have enhanced the value of the paper considerably had the author been able to go into more details of the work, even at the risk of saying something which might have been known to someone else, and to have shown, if possible, a map of the various preliminary lines run and their relation to the final located line, and to have given some details of the cost of the surveys and the time consumed in making them.

Mr. Taylor states as his fourth principle, in making such surveys as this, the necessity of making "a diligent study of the whole country." Evidently, he did this, before the completion of the work, but fuller details of how much country the reconnaissances covered, how much time was spent on them, and how the final results were deduced from these observations, would have been invaluable, to experienced engineers as well as to students.

It hardly seems possible that railroads to-day are located in any other than a big, broad-minded way, with time and money enough to do the work thoroughly, and to thrash out the country until absolute proof is obtained that the best line has been selected.

The speaker, however, knows from a rather extended experience that, in spite of all that should be known of the increased cost of operation of badly located roads, many miles of railroad are being located and built now in the same old narrow-minded way, and this is the cause of the large expenditures which are being made for relocations and revisions. Many men, investing in railroad projects, still believe that any money spent on engineering, and especially on location surveys, is just so much money wasted.

An instance has come under the speaker's observation recently. On what is now part of a trunk line, and between two points, about 200 miles apart, by the present operated line, a new line has been located, saving more than 30 miles of distance, with ruling grades of one-half of those on the older line, saving nearly 3 000 ft. of rise and fall, and having less than half the total degrees of curvature of the older line. This does not necessarily imply a criticism of the older line, as the speaker does not know any of the conditions under which it was located and built or the relative cost of the two lines, but it illustrates what can be accomplished by a thorough study of the country and by properly conducted surveys.

It seems strange that the author has offered no explanation of the fact that so many changes were necessary after construction was started. It appears that the route had been under consideration, more or less, for the past twenty years, and surely, at least a decision as to ruling grades and the general location of the line, if not of the minor details, should have been reached before construction was commenced.

It is stated that, when it was found that 0.65% grades could be obtained on this new line, this required changes in minor grades on the part on which construction had already started, and caused the officials of the Louisville and Nashville to determine to make some grade revisions on the old lines which this link connected. Mr. Lavis.

Surely this new line and the whole freight division of which it is a part should have been studied as a whole, to determine the ruling grades possible on the whole division, and a thoroughly comprehensive survey should have been made before construction was started.

One of the grave errors, even to-day, in a great deal of the grade revision, is that it is not comprehensive enough, and the work is done in little pieces.

It does not necessarily follow that, because a comprehensive scheme has been laid out, the work has to be undertaken all at once, but the work done should be governed by its relation to the whole.

It is hardly possible, from the information contained in the paper, to estimate the value of the change from the 1% to the 0.65% grade on this short piece of line, without knowing its relation to the operating division of which it will form a part.

In speaking of the rates of grade, the author uses indiscriminately rates per mile and rates per cent. Rates of grade in this country, at least among engineers, are now spoken of almost exclusively in rates per cent., and it would seem advisable to use this method of nomenclature exclusively, at least in an engineering paper.

In reference to the Missouri prairies: The word, prairie, generally conveys to the average reader an idea of a comparatively level plain, but some of the most difficult location can be found through the Missouri and Iowa prairies, especially for low grade lines. Mountain ridges may be bucked through, but the long rolling country, with differences between ridges and valleys often amounting to more than 200 ft., such as found through Missouri, broken up by cross-drainage, presents some of the most difficult problems in railroad location. The line has to go down into valleys and over ridges, and the slopes are almost always just too steep for the grades one is trying to get.

W. H. COVERDALE, ASSOC. M. AM. SOC. C. E.—The author is to be congratulated, both upon his location of the line between Knoxville and Jellico, and upon his description of the work. The locating engineer always delights to narrate his troubles; but, unlike the author, he does not always succeed in making the narration attractive. Mr. Coverdale.

The topography of this section of country, as may be seen from a glance at the map, is enough to strike terror into the heart of the engineer who is looking for a railroad of easy grades and tangential alignment between the points named.

Not only does the backbone of the Cumberland Range interpose a rugged barrier some 500 to 600 ft. higher than either terminus, but

Mr. Coverdale. series of subsidiary ridges, parallel to the axis of the mountain and divided by deeply-eroded valleys, point their forbidding fingers across the path; and precipitous torrents, at widely-varying elevations, roar their challenge of defiance.

The author, in all probability, has secured the best location which the country—and his company—affords. He states frankly that the grade reduction, which left one pusher grade on the road, was an afterthought, considered only when much construction work had been done; hence the relation between the maximum ordinary and pusher grades needs no criticism. All in all, the result of his work can be but a matter of congratulation. The method by which the result was secured is the subject matter of this discussion.

In any topic as comprehensive as that of railroad location, much of interest must necessarily be omitted from a paper, which the author does not intend as an exhaustive treatise; and, indeed, the author states that he has not mentioned that part of the work upon which he spent most of his energy. This probably means the reconnaissance feature, as he emphasizes the importance of a diligent study of the whole country; and if this assumption be correct, an ignorant, but interested, reader of the paper would respectfully ask that, before the discussion be closed, the author give some idea of the amount of such work which was necessary in the development of this line. A thorough reconnaissance and the method of selection of the primary points on the route is not a narrow and detailed question, but a broad determination of policy upon which must rest the vindication of the located line. The fact that the author speaks definitely of the features of Copper Ridge for a distance of 30 miles from the point where he crossed it throws a little light on the scope of such work.

About seven years ago the speaker drove more than 20 000 miles, looking for a 20-ft.-per-mile grade for the Pittsburg, Ft. Wayne and Chicago Railway, between the Ohio River and the prairie country, some 200 miles to the westward, and he recalls the narrow and prejudiced state of mind in which he was when he began the work. A summit, lower than the one over which this line was laid, and in plain sight of it, meant nothing to him but that the locating engineer had been in error, while a detour of 10 or 50 miles, if it afforded the required grade, was the one route which should have been considered seriously. Such matters as excessive cost of construction, failure to serve important centers of population, greatly increased mileage, etc., were mere bagatelles when weighed against the reduction of ton-mile cost.

However, a little good advice from his chief engineer soon put him in a more tolerant attitude, and he began to realize that topography is but one of several factors, and too often an unknown one at that, in the transportation equation.

This suggests a second point to which the speaker wishes to call attention, namely: Men of a previous generation must not be judged by present standards, and this is equally true of technical skill and of morality. Who shall say that the old Portage Road across the Allegheny Mountains was not the proper answer to the stage-coach problem? Who shall say that Hernando Cortez and Nero were cruel men? Mr. Coverdale.

The author compares his grade of 34 ft. per mile with that of 66 ft. per mile existing on rival roads. He also states that his total average rise and fall per mile is only 21.5 ft., as against 59.2 ft. for the old road. He states, further, that his road is smoother than an unnamed prairie road by 42 per cent. These facts are pertinent and interesting, but they are disjointed, or, rather, isolated; and, in all fairness, the inference that the first railroad through this country should have been constructed on the location described by the author must be avoided.

Many other facts must be added to those stated by the author before the chain of cause and effect can be completed, as, for instance, the cost per mile which secured the 34-ft. grade, as against the cost of the 66-ft. grade, the length of the respective routes which exceeded the straight-line distance by 34 and 55% in favor of the old route, and the general traffic and commercial conditions obtaining at the respective dates of construction.

Because men built railroads on a 1% maximum grade fifty or twenty years ago, it by no means follows that they built badly, and their work must not be judged by the conditions under which work is done to-day. Increased traffic, competition, reduction in ton-mile revenue and other considerations to-day make easy gradients imperative and economic, which, a generation ago, would have been the height of folly; and it may even be possible that this "widow's mite" railroad, running up and down and across country, over the hills and hollows—on which, it may be, the old rails have a hard time to keep the fire-box off the ties—may have represented as nice an adjustment of means, methods and results as the author's modern road.

In regard to grade revision and the method of determining the amount which could be spent economically for tunneling, it is noted that the author's estimates are based upon a 2 170-ft. tunnel at Copper Ridge and a 700-ft. tunnel at Black Oak Ridge No. 2. The actual construction work, however, was not carried out on these lines. The town of Clinton, with its contiguous 700-ft. tunnel, was weighed in the balance against the town of Dosset and the claim of the Oliver Springs Branch, and found wanting, and so a sweeping change of location was made and a tunnel 3 520 ft. long was substituted for the 700-ft. tunnel.

The total length of main-line tunnel, therefore, is 5 690 ft. instead

Mr. Coverdale.

of 2 870 ft., or practically double the length used in estimating. It is beside the question to offset the additional cost of main-line construction against the saving on the branch line because main-line construction costs must be justified by main-line traffic results.

Furthermore, although by this plan the grades on the branch line were reduced to the main-line ruling grade against south-bound traffic, and although, theoretically, this is very nice, yet grades of coal branch lines are by no means as important as main-line grades, and for several reasons:

1.—Through main-line freight trains do not travel over such branches, nor stop at such junction points to take on loads or set off empties, except in rare instances.

2.—Trains running light and filling to capacity at local points are rarely a factor in grade determination.

3.—Local trains deliver empties to mines and collect loads therefrom, and seldom work up to full engine capacity.

4.—Coal branch grades are with, rather than against, their traffic, and a grade of 34 ft. per mile, over which to shove merely empty gondolas, is an expensive luxury.

It appears, therefore, that the author's estimate of what the 34-ft. grade would cost should have included all main-track work as actually built. Since it is not apparent from the paper what the increased cost of the 5 690 ft. of tunnel is over that portion of the original line which it displaces, it would not be pertinent to subject the author's estimate to detailed examination.

It is pertinent, however, to call attention to the idea which pervades the argument expressed on page 140:* "Operating expenses vary directly as the train-mileage," and to be satisfied that this premise be a sound one before accepting the conclusion.

The *Transactions* of this Society contains a memorial of that great railroad economist, Albert Fink;† and even from those brief notes may be learned the fact that his first analyses of railroad operations were embodied in the annual reports of the Louisville and Nashville Railroad about thirty years ago.

Mr. Fink's writings upon this subject are still classics, and it is of interest to note that the officers of the very railroad, the records of which contain so much that is practical and scientific, acquiesce so readily in the empirical theory which the author states as a fact.

Revenue train-mileage is a unit of service by which may be measured the cost price of transportation. To say, however, that this cost price varies directly as the total amount of transportation sold, is to disregard all the primary-construction cost of the property, much of the maintenance, and a considerable amount of the costs incidental to train service and general expenses.

* *Proceedings*, Am. Soc. C. E., February, 1904.
† *Transactions*, Am. Soc. C. E., Vol. XLI, p. 626.

The Inter-State Commerce Commission classifies railroad operating expenses under four main headings: Mr. Coverdale.

1st.—Maintenance of way and structures,
2d. —Maintenance of equipment,
3d.—Conducting transportation,
4th.—General expenses.

A brief examination of these expense items will show to what extent they vary as train-mileage:

1.—"Maintenance of way and structure expense" "fluctuates, not with the rate of wear, but with the rate of renewal," says Mr. Eaton, the statistician of the Lehigh Valley Railroad, in his book on "Railroad Operations." The character and amount of traffic determines in a general way the types of track and bridge structures, but large sums are spent annually for maintenance of such structures, and appear in the figures which the author has used, which have nothing whatever to do with train-mileage.

Widening banks, sodding slopes, cutting weeds, repairing fences and track signs, many tie renewals, painting bridges and buildings, renewing bridges and buildings destroyed by fire, flood, or lawlessness, the substitution of steel and masonry for wooden structures, grade reductions, revisions of alignment and other betterments of magnitude not chargeable to capital account: All these items of operating expense depend in no way upon the train-mileage.

The "maintenance of way and structure" item, for the Louisville and Nashville Railroad, amounted, in 1902, to about 22% of the entire charge against operation; and, of this amount, only 33⅓%, or 7% of the whole, is chargeable to train-mileage. This apportionment is made on the basis of the Pennsylvania Railroad methods, and includes all renewals of rails, frogs and switches, 33⅓% of cross-tie renewals and 10% of repairs of roadway, track and bridges. All repairs of buildings, docks and structures, other than above, are taken as independent of train-mileage.

2.—"Maintenance of equipment expense" varies with engine-mileage, freight and passenger car-mileage, but not with train-mileage. It depends upon alignment and grade of line, weather, speed and accidents; it includes cost of marine-equipment maintenance, interest on shop investments, etc. This item, for the Louisville and Nashville Railroad, amounted, in 1902, also to about 22% of the entire charge against operation, and cannot be said to vary directly with train-mileage. It is noted that, while repairs to locomotives, passenger and freight cars, etc., are the direct result of operation, yet a unit of maintenance, much more exact than train-mileage, is now in general use.

3.—"Conducting transportation" is usually subdivided into twenty-five or more accounts, including fuel, water, locomotive and

Mr. Coverdale. miscellaneous supplies, wages of engineers, firemen and roundhouse-men, switchmen, flagmen, station supplies, advertising, telegraphing, car-mileage, injuries to persons and property, etc., etc., and only one of these accounts, namely, train service, which covers the wages of conductors, baggagemen, brakemen and flagmen, can be said to vary directly with train-mileage. This item, for the Louisville and Nashville Railroad, amounted, in 1902, to about 52% of the total operating expenses, and of this amount only 13% varies with train-mileage.

4.—The item "general expenses," of course, does not vary with train-mileage, so that, in all, about 14% of operating expenses depends upon train-miles run, and upon this slender thread hangs all the weight of the author's argument.

Several other points are suggested, but they are of a more or less detailed nature, and are, in consequence, omitted. The speaker has derived both pleasure and profit from a perusal of the paper.

Mr. Linton. HARVEY LINTON, M. AM. SOC. C. E. (by letter).—The writer finds little to add to Mr. Low's excellent description of the location of the Clinch Valley Division of the Norfolk and Western Railroad.

Whatever reconnaissance was made in 1886 afterward had to be modified considerably. The line between St. Paul and Little Tom Tunnel was fixed upon before any survey, other than the writer's reconnaissance, had been made.

Early in the spring of 1887, the writer rode from Graham, Va., to Big Stone Gap, Ky., after having spent about two weeks in charge of the first surveying party in the field, on Bluestone, above Graham. Arriving at Big Stone Gap, he met there the late R. L. Cobb, M. Am. Soc. C. E., then Chief Engineer of the Louisville and Nashville Railroad. After a few days at Big Stone Gap, the writer rode back, over the line, looking into the valley of Guest River, and exploring the ridge between Russell and Bull Creeks. A good aneroid, and a pedometer which had been calibrated with the horse's step to read miles, were of great service in this work.

It was soon evident that something unusual would have to be done, to get a railroad location from Clinch River to the valley of Powell River. Guest River, from its mouth up, although described previously* as "the natural gateway to this region," was simply impossible. The valley of Bull Creek is like a deep cañon. A location down the Clinch River and up Bull Creek did not look promising. After starting with an ascending grade from Lick Creek (St. Paul), Creagan Tunnel is necessary, to get from the valley of Whetstone Creek to the valley of Russell Creek. After that, the "awful" profile that the location developed had to be accepted; there was no alternative. This the writer stated to Mr. Coe, on his return to Roanoke, when he made

*In d'Invillier's Geological Report to the Norfolk and Western Railroad Company.

a large sketch, in red and blue pencil, of the location which was afterward adopted. Mr. Coe accompanied the writer on his next trip, and was convinced that this was the best location. Later surveys proved it. Altogether, it was an interesting experience. Mr. Linton.

Mr. Oramel Barrett in 1887 made a survey down Guest River, so as to hold that route against the Norfolk and Western Railroad Company. The writer made no survey down Guest River, below the present line of the Norfolk and Western. The Lewis Creek and Thompson Creek lines were developed later in the season, after surveys had been in progress some time.

The summit of Bluestone (near the highway) was found, by aneroid, to be, approximately, 100 ft. higher than the summit of Wright Valley Creek. This led to the adoption of the location over Wright Valley Creek Summit.

Mr. Low's remarks relative to the organization and methods of field parties are very good. Before the surveys for the Clinch Valley location were finished, notes were sent to the office, at Tazewell Court House, and there plotted.

W. T. Forsythe, Esq. (by letter).—In the location of the Knoxville, La Follette and Jellico Railroad the writer does not think the difficulties to be overcome were as great as those presented in the Clinch Valley Division of the Norfolk and Western Railroad. The topography of the country, or, rather, of the valleys, is very dissimilar, and is generally supposed to be caused by faults in the vicinity of Pineville, Tenn. The Middlesboro Basin is practically the same as the basin at Big Stone Gap. This is separated from the Jellico Basin by an unproductive belt, about 6 miles in width, where the Lee Conglomerate is found as the overlying rock, under which, as under all conglomerate rocks in Pennsylvania, no bituminous coal is found in place. Jellico is on or near the eastern edge of the Jellico Basin, and the coal measures in that basin are the upper measures of the Pocahontas Series, while those of the Middlesboro Basin represent the No. 3 or Pocahontas vein. The upper measures are not nearly as pure as the lower measures. Mr. Forsythe.

The coal-bearing rock series of this formation thicken on the southeast border, the elevation of the veins is increased, and they finally vanish.

The rocks east of a certain point have been eroded more, being softer, until the limestone formation, peculiar to the Clinch Valley, is reached.

The general direction of the coal measures, when no displacement has occurred, varies from N. 30° E. to N. 40° E. in this section, which is the general course until the Susquehanna River in Pennsylvania is reached, when it is deflected more to the east, and the anthracite coal series prevail, no anthracite coal being found west of the Susquehanna or east of the Lehigh.

Mr. Forsythe. The Clinch Valley Railroad, being located southeast of the coal-bearing series of rocks, is in the district most affected by erosions. Thence the streams are more winding. The upheaval of the limestone caused a diversion at Young's Summit, and all along the line in Tazewell County as far as Cedar Bluff this rock asserts itself. The particular feature which the writer wishes to show is that the strata southeast of this line of the Pocahontas vein are broken, from Birmingham, Ala., to New York State.

Northwest of this line the strata are nearly horizontal, and are broken very little for a distance of nearly 100 miles. The coal beds thin out toward the northwest and dip in that direction, with a few anticlinals, until they are too deep to be workable. The coal-bearing rocks of the Kanawha Series become the producing strata, until they take the same dip in a northwest direction, and are overtopped by the Pittsburg formation, which is the upper formation and is distinguished from the other by being semi-anthracite in character, in many places.

The rocks through which the Big River forces its way are not displaced, as in the Clinch River, and therefore the sinuosities are not as common.

On the Clinch Valley Division of the Norfolk and Western the Creàgan Tunnel is the last of the limestone ridges penetrated. The time allotted to the survey of the territory lying between the mouth of Thompson Creek and the mouth of Guest River, and up Guest River to the vicinity of Coeburn or the mouth of Big Tom, was scarcely sufficient.

A careful survey should have been made from Keyser Tunnel, near the mouth of Dump Creek, over the dividing ridge between Dump and Lick Creeks, and again over the ridge to the headwaters of Little Tom. Thus, the tunnels, when necessary, would have been through sandstone altogether, and the coal-bearing strata would have been reached in shorter distance from Graham, and the coal fields traversed a longer distance. The fall of Guest River, from its source to a point below the mouth of Big Tom, is at the rate of 120 ft. per mile.

Russell Creek Valley is 100 ft. higher than Bull Run Valley at opposing points. Therefore, it might have been better to have made one tunnel from Whetstone River into the Russell Creek Valley and another tunnel into the Bull Run Valley at the head of Lawson's Hollow, where the 150-ft. trestle was built, being the nearest of the high trestles to the Little Tom Tunnel; thus, instead of the Creagan Tunnel, the heavy cut in the gap into Russell Creek Valley, the Big Bull and Little Bull and Holbrook Tunnels, the dip in the crossing of Russell's Creek, the high trestles (one of 100 ft. and two of 150 ft. each) might, perhaps, have been avoided, and two tunnels, rather longer than any one of these, but not measuring more than 75% of the total tunnel distance, would have been substituted.

The saving in cost might have been considerable, and the gradient reduced to at least 1.25 per cent. As mentioned before, the time was short and the season very unfavorable for a survey, as there were many rains during the twelve weeks devoted to this region. Mr. Forsythe.

The writer has made extended examinations of the eastern outcrop, from a point near Chattanooga, Tenn., to Broad Top, Pa., and has been confirmed in the developments when found. The Cumberland Plateau is mostly an unbroken mass of rock, and the coal measures have few faults and very little parting, or bony coal; both to the northeast and southwest some displacements are found, and in such places more bone is found and sometimes the veins have two partings instead of one. Nothing would have been gained by going down to the mouth of Bull Run—there would only have been more grade to overcome. It rises most abruptly in the upper portions of the valley, and the fall is very gradual from Lawson's Trestle down.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

FREEZING AS AN AID TO EXCAVATION IN UNSTABLE MATERIAL.

Discussion.*

By Messrs. H. J. Campbell, A. Gobert and James H. Brace.

Mr. Campbell. H. J. Campbell, Esq.—This paper is of very great interest to the speaker. The author's painstaking care in compiling so carefully the history of this mode of excavating merits much praise, and it will surely be of great value to the engineering profession.

A writer of the history of artificial refrigeration can record but little practical progress antedating the last quarter of a century; consequently, it is apparent from the paper that the engineers were among the first to grasp its utility and apply it as a successful means to accomplish an end, which, before its advent, had well nigh defeated their efforts. It is observed that many of the early attempts to excavate by this process were successful only after much delay, others were only partially successful, and others were total failures. As it was not until the early Eighties that refrigerating systems began to be perfected so as to be relied upon, undoubtedly a large number of these failures were due to the crude machinery used and the lack of attention to essential details in installing the plants.

It is of the utmost importance, in undertaking excavation by this process, that careful observations be taken to determine the nature of the material, its specific and latent heat, and its conductivity of temperature, as on these data will depend the determination of the best means to be used in applying the refrigeration, and the amount that can safely be relied upon to accomplish the work successfully.

*Continued from March, 1904, *Proceedings*. See January, 1904, *Proceedings*, for paper on this subject by James H. Brace, Assoc. M. Am. Soc. C. E.

If pipes are to be sunk into the ground, as in excavating a vertical shaft, their spacing and arrangement should be governed by the varying nature of the material on the different sides of the shaft, rather than by spacing them evenly, as has been usual. Mr. Campbell.

If the work is in horizontal shafts or tunnels, it is important that the arrangement be such as to ensure an even freezing entirely around the shaft, which can only be accomplished by bringing the pipes, through which the freezing agent passes, into absolute contact with the material to be frozen.

There is one matter which the speaker considers of importance, if the quickest success would be attained, namely, that the refrigerating agent be metered to the different series of pipes used, and its return temperature taken, in order to determine the amount of work being done at each point and the progress being made, which, further, serves as a check on the previous examinations.

A perusal of the paper indicates that, even in the latest work, the most modern machinery was not used. Had that been done, much time would have been saved in erection, and the freezing would have been accomplished very much sooner, as the brine could have been carried at a temperature from 8 to 12° lower. Further, the intensifying of the temperatures would have gone far toward ensuring the success of the work, and would have reduced its cost materially.

Up-to-date machinery is now self-contained, quickly erected or taken down, and of such design that when standing idle it will not deteriorate to any great degree—no more than, and possibly not as much as, an ordinary pneumatic plant.

Among the opportunities which have come to the speaker's knowledge where refrigeration could have been used to great advantage and would have saved much time and money may be mentioned the tunnel under the Harlem River for the new Croton Aqueduct.

In order to determine the depth necessary to go below the bed of the river to ensure solid rock excavation for the entire tunnel, frequent borings were made across the river, and showed that at a depth of about 150 ft. below the surface the rock was solid. The tunnel was started at that depth, but, after proceeding for about 300 ft. a pilot drilling developed an 18-in. seam in the rock. This seam was heavily water-bearing, so much so that further excavation on that level was abandoned and a bulkhead was put in to prevent future trouble. Further test borings were made, and it was discovered that this fault in the rock was between those borings made previously, and that, otherwise, the rock was sufficiently solid at this elevation to have been excavated by the ordinary means; but in order to avoid this seam it was necessary to go 155 ft. lower, where the rock proved to be perfectly solid.

As rock is a good conductor of heat and cold it would have been comparatively easy to have frozen this 18 ins. and then proceeded on

Mr. Campbell. the level at first determined, thereby saving to the city from $75 000 to $80 000 in first cost and the expense of pumping out this extra depth of shaft whenever it is desired to examine or clean the tunnel. There were other points on the Croton Aqueduct where artificial refrigeration could have been used to great advantage.

This tunnel work and the Speedway are on the same side of the Harlem River. The engineers informed the speaker that they had determined by pilot drilling that this 18 ins. was the only stratum which was too heavily water-bearing to have prevented their excavating at that elevation, and as the rock has a low specific heat and is a good conductor of heat and cold, and as the water was undoubtedly stagnant, there is no doubt that it could have been easily frozen for excavating.

As to the work on the Speedway, it is understood that the material which it was attempted to freeze was quicksand, which would indicate that the conditions were entirely different from those on the Croton Aqueduct and more uncertain. The speaker knows nothing about these conditions or how the refrigeration was applied, consequently he is unable to state why the work was not successful or whether refrigeration could have been applied so as to have been successful.

The science of artificial refrigeration has advanced to such a point that the engineer should have it in mind as a means of accomplishing difficult excavation which, heretofore, has been done by more crude and expensive means.

Mr. Gobert.

SHAFT SINKING AT A GREATER DEPTH THAN IS POSSIBLE BY THE KIND-CHANDRON PROCESS.

In this case, the soft ground is filled with salt water which prevents the application of the freezing process.

Fresh water is pumped into the place occupied by the salt water.

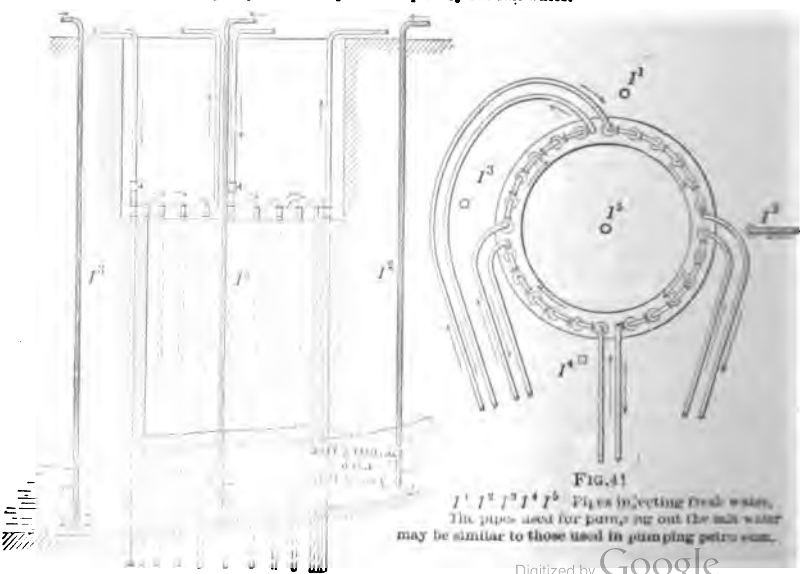


FIG. 44

I^1 I^2 I^3 I^4 I^5 Pipes injecting fresh water.

The pipes used for pumping out the salt water may be similar to those used in pumping petroleum.

FIG. 43

A. GOBERT, Esq. (by letter).—The shaft at Ronnenburg could not be completed by the freezing process, because the ground-water contained too much salt. Mr. Gobert.

In the new coal field of Campine, in the north of Belgium, and in other places on the left side of the Rhine, much salt water is found at a depth of, say, 600 m., and is thus beyond the limit, 400 m., ascribed to the possibilities of the Kind-Chandron process. The writer, therefore, proposes to pump the salt water from the soft ground, in the same way as petroleum is pumped, and then pour in fresh water to take its place, thus rendering freezing possible.

This idea is shown clearly in Figs. 43 and 44.

All the writer's recent patents are based on the circulation of brine; he has abandoned the idea of evaporating ammonia in the freezing tubes.

JAMES H. BRACE, ASSOC. M. AM. SOC. C. E. (by letter).—In preparing this paper it was the writer's purpose to show where information was lacking, as well as to summarize that available. Many of the uncertainties in regard to the use of the freezing process at various points could be cleared up by those who were in direct charge of the work. The writer is somewhat disappointed that the discussion has not brought out more particulars in this respect. As Mr. Moran states, all the gentlemen interested in the use of the freezing process in this country are members of this Society, and the writer hoped that they would join in making the record complete, at least as far as America is concerned. Mr. Brace.

There are many factors yet to be determined before accurate estimates can be made in advance as to the time required for, and the cost of, any particular work. Theoretical study will prove very valuable in pointing out the nature of the problem and the elements for which the values are to be determined. The values of these elements, however, can only be determined by observations in actual practice, supplemented by laboratory experiments. Those in charge of the work at the Vicq Shafts made a start in the right direction, and some information was also collected at the Chapin Mine.

In planning future operations by the freezing method, it is to be hoped that a detailed system of observations for determining the unknown factors will be planned in advance and then carried out faithfully. In this way the freezing process can soon be placed on a definite basis, and will command the confidence it undoubtedly deserves in certain classes of work.

Mr. Campbell has suggested that modern machinery would enable the use of much lower temperatures. It is no doubt possible to produce much lower temperatures than any that have been used thus far in the freezing process, but the writer has been unable to ascertain the lowest temperature at which it is practicable to circulate calcium

Mr. Brace. chloride brine. This temperature might prove to b
dition, rather than that which could be produce
machine.

In conclusion, it may be of interest to note tha
few weeks, the freezing process has been used, on a
Louis, to stop a leak in a steel coffer-dam. The p
are rather meager, but, apparently, the attempt wa

VOL. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

SUBSTRUCTURE OF MARSH RIVER BRIDGE.

Discussion.*

BY GEORGE B. FRANCIS, M. AM. SOC. C. E.

GEORGE B. FRANCIS, M. AM. SOC. C. E.—The Society is indebted to the author for his good description of the work done. The paper describes a method of lowering a masonry pier, built on a timber platform, to its final bearing on a pile foundation, by long screw-bolts, with the threaded end of the bolts at the top, the lowering having been effected by turning nuts on these bolts. In 1888 the center pier of a single-track draw-bridge at Oakland Beach, R. I., was placed, in this manner, under the speaker's direction, with the exception that the rods were reversed, *i. e.*, placed with the threaded ends down and with the nuts boxed into the underside of the timber platform. The pier was lowered by turning the heads of the bolts, instead of the nuts. This was necessary because the track grade was near the water and the old draw was frequently turned for the passage of boats; if the bolts had been set with the screw ends up it would have been impossible to swing the draw. Mr. Francis.

In 1892 the end piers of the double-track draw-bridge, on the Shore Line, at Mystic, Conn., were lowered in the manner described by the author. Under certain conditions this method proves very economical and effective, particularly where the amount of lowering required is moderate and the difficulties of coffer-damming are great.

*This discussion (of the paper by Herbert J. Wild, Jun. Am. Soc. C. E., printed in *Proceedings* for February, 1904), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to May 27th, 1904, will be published subsequently.

Mr. Francis. The speaker has had no especial difficulty in sawing off piles under water with a circular saw on a shaft placed in pile-driver leaders on a scow. The binding of the saw experienced by the author was probably due to the light scow used. It will probably be remembered that A. P. Boller, M. Am. Soc. C. E., had piles cut off in this manner, about 50 ft. under water, at the Thames River Bridge, New London, Conn. It is difficult to saw the piles off at an even grade, owing to the rise and fall of the tide and to some surging of the scow. Even at the moderate depth of 6 ft., the writer found it difficult to saw off a cluster of piles within 1 in. of the proper grade line (measured up or down), or within a range of 2 ins.

At great depths, like 50 ft., records obtained with a steel tape line have shown that it is difficult to cut off piles within 2½ ins. of the proper grade line, or within a range of 5 ins. In such cases it is expected that the weight of the masonry on the platform grillage will crush the timber until the platform comes to an even bearing on the piles.

Exception has been taken to the author's conclusion that it is preferable to use divers, rather than machinery, to cut off piles under water, and the opinion has been expressed that divers are about the most unreliable agents that can be used. The speaker thinks that much depends on the experience of the divers employed. No doubt, some are unskilled on construction work under water who would be skilled on other work. In constructing the Boston Terminal, occasion required the removal of some crib timber buried in gravel filling under water, and certain local divers were employed for the work. They spent many weeks in the attempt, making very little progress, and then practically confessed their inability to do the work. In despair, the contractor for the terminal work turned to the writer for advice, and was directed to send for a certain diver experienced in wrecking and construction work under water. This was done, and, although the cost was large, the work was executed promptly. Such a diver will succeed in this class of work where many others fail.

Vol. XXX. APRIL, 1904. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

METHOD USED BY THE RAILROAD COMMISSION, OF TEXAS, UNDER THE STOCK AND BOND LAW, IN VALUING RAILROAD PROPERTIES.

Discussion.*

By R. A. Thompson, Assoc. M. Am. Soc. C. E.

R. A. Thompson, Assoc. M. Am. Soc. C. E. (by letter.)—The writer, while admitting that grave objections may be raised to the methods used by the Railroad Commission of Texas in valuing railroad properties under the provisions of the Stock and Bond Law, believes that other objections, some perhaps more serious, might be raised against any other system of valuation that could be formulated, and that it is probable that the Texas Law, when administered fairly and impartially, is as fair and just, both to the railroads and the public, as it is possible to provide. Mr. Thompson.

As the law now stands, it is susceptible of considerable freedom of application, and, under such limitations as "to promote public interests and protect private rights" and "public interests and the preservation of the property," no one will maintain that a fair and

* Continued from March, 1904, *Proceedings*. See January, 1904, *Proceedings*, for paper on this subject by R. A. Thompson, Assoc. M. Am. Soc. C. E.

Mr. Thompson. reasonable tribunal has not ample opportunity to mete out just and liberal treatment to the railroads, and, at the same time, give the people the protection contemplated by the law. It is left absolutely to the discretion of the Railroad Commission to authorize the issuance of stock and bonds 50% in excess of the value of the railroad property.

That the law and the methods used by the Commission in valuing railroad property have not entirely discouraged railroad building in Texas is shown by the fact that since the passage of the law more than 2 000 miles of railroad have been built, both by trunk lines and by small independent corporations, and have been paid for by securities issued under its restrictions. This is evidence that the law does not hamper or entirely thwart legitimate railroad construction. The hue and cry raised against the law and its administration can in every case be traced to someone who does not understand its provisions, or to some old promoter whose avocation of building railroads for purely speculative purposes—intending to reap profits out of bonuses and questionable construction contracts—is practically destroyed.

Mr. E. L. Corthell asks:

"Would it not be more reasonable to obtain the contract prices paid by the company in constructing its railroads, and the actual cost from its books when doing the work by its own day labor?"

Assuredly, such a practice would be advisable, and, as a matter of fact, such is the practice actually carried out by the Commission whenever it is possible to obtain the information. When valuing new properties, the Commission requires that all original contracts, for construction of every character, be submitted for its inspection, together with the company's estimates of the actual quantities of all kinds of construction. The estimates of value made up from these are intended to be liberal, and, if anything, more than cover the actual cost. All the original right-of-way deeds, franchises, etc., are filed with the Commission for examination, and a liberal allowance is made for the value of right-of-way, depot and terminal grounds, in accordance with what appears to be the actual market value of the property, including a certain percentage, in addition, for damages that may or may not have been paid to abutting property owners. No deduction is made for the value of property which may have been partially or wholly donated.

The Commission has the figures of actual cost in every case where they can be obtained. In the case of old railroads, existing at the time of the passage of the law, except in a few instances, the construction records, notes and sometimes even all the original maps and profiles, had been destroyed, mislaid or carried out of the State. A number of the lines had been built by construction companies for such stock and bonds as may have been issued, and no records or estimates of cost were ever turned over to the railroad companies.

It should be borne in mind at all times that the Commission was

directed by the law to make an "estimate of value," and not an "estimate of cost." Of course, it was the intention of the law that the "estimate of value" should be, to some extent, based on the actual cost, where such cost was reasonable to the company, but the actual cost cannot be adopted as the basis for value in every case. As a physical proposition, a yard of earth has the same value in one railroad as in another in contiguous territory, although the actual cost in one case may have been 10 cents, while in the other it may have been 16 cents, per cubic yard. If 16 cents per cubic yard be considered by the Commission as the value of earth for one railroad, to be consistent, it must also value earth in the other at 16 cents per cubic yard. The fact that one company was able to let its earthwork by contract for less than the other company does not make its earthwork less valuable in the eyes of the Commission. **Mr. Thompson.**

The writer, certainly, is not one to contend that "seasoning" of the roadbed of a railroad does not in a sense add to its physical value. It is valuable in many ways, *viz.*, the maintenance charges per mile are less, the danger of accidents is decreased, the wear and tear on rolling stock is less, etc. But the question to be decided by the Commission, when establishing its methods of valuation, was whether or not such value was mortgageable, and, if so, how could its value be ascertained. The expense of "seasoning" is properly charged, through roadbed account, to maintenance, and does not appear in the "permanent improvement" or "capital" accounts. It involves no additional outlay of capital by the owners of the road, in the sense that other permanent improvements do, and hence is not value that should be mortgaged; that is, interest charges should not be permitted to be collected thereon. In accordance with the decisions of the Federal Courts, the Commission must permit sufficient rates on freight to enable the railroads to earn, in addition to operating and maintenance expenses, a fair rate of interest on the value of the property. Had it recognized that "seasoning of roadbed" was an item which must be valued in determining the amount of stock and bonds which a railroad could issue, it would have been in the position of imposing a double charge on the public on account of such value, *viz.*, the original cost of such "seasoning" and an annual interest on such cost.

Mr. Corthell is decidedly in error when he states that:

"The estimate on which to base the permitted issue of stocks and bonds is made upon the report of an engineer who goes over the road with a profile and estimates his quantities from center heights."

Up to this time, in the history of the Commission, there has never been an instance where stocks and bonds have been issued on this basis. In all cases that have come up the railroads have been able to supply the Commission with the actual quantities of graduation. The only instances when the approximate method was used were in the

Mr. Thompson. valuations of some of the older railroads, already mortgaged, the actual quantities of graduation for which were unobtainable from any source, and it is probable that, when these properties come up hereafter before the Commission, with application for issuance of new mortgages, accurate surveys will have been made, and, if the estimates offered are considered by the Commission to be correct, they will be adopted by it.

Under the Law, Article 4584 c, "to promote public interests and protect private rights, the Commission may correct its report of value of any railroad at any time it may deem proper." The valuations which have been made and published by the Commission are not necessarily, as Mr. Corthell appears to assume, entirely permanent. A new valuation can be ordered whenever the Commission considers that justice demands it, and the Commission is composed of just and reasonable men. The chief function of the Commission in this particular, as is emphasized by the Stock and Bond Law, is to see that the stocks and bonds hereafter issued by a railroad do not exceed a "reasonable value of its property." Whenever application is made by a railroad for authority to issue stocks and bonds, it becomes the duty of the Commission to ascertain the value of the railroad property at that time, and the value of all permanent improvements, equipment, etc., that have been added since any former valuation, must necessarily be included. Although, up to this time, only one case of this kind has come before the Commission for action, it is considered that under the law it has no discretion in the matter, and must revalue a railroad whenever application is made and the occasion demands.

Since most of the railroads of Texas were valued in 1894 and 1895, just after the passage of the Stock and Bond Law, it must not be supposed that the Commission holds that they are worth no more to-day, as a basis for issuance of securities, than at the time of valuation. The average valuation per mile of those railroads which have been valued is, as stated in the paper, \$16 120. It is highly probable that, if a revaluation were ordered to be made now by the Commission, on the same basis as used formerly, this average per mile would be increased several thousand dollars on account of the great amount of permanent improvements and equipment that have been added to the railroads during the past ten years. The value of these improvements, and a reasonable amount for appreciation in all real estate, would have to be added to the former valuations.

An important feature of the Texas Railroad Stock and Bond Law, one that should not be overlooked by anyone attempting to criticise it and the methods of railroad valuation it prescribes, is the enhanced value it has given to railroad securities in Texas. A comparison of the market value of the stocks and bonds of the railroads of Texas to-day with those of ten years ago will convince the most skeptical of this

fact. The writer has in mind one railroad, which was in the hands of a receiver at the time of the passage of the law, and which recently built an extension. The bonds issued by this railroad, to the value of this extension, under the order of the Commission, sold, on the average, for 108, of itself a handsome profit on the capital involved, exclusive of the liberal donations of land and money which the company received from the communities penetrated. These were 5% bonds, and, had 6% bonds been issued, the limit allowed by law, the profit from their sale, probably, would have been greater. Certain Texas railroad securities which were hawked about the brokers' offices of Wall Street and, with difficulty, found sale at 40 and 50, ten years ago, would now find ready purchasers at par or a little less, had they the stamp of approval of the Railroad Commission. Mr. Thompson.

Another significant fact is that only a short time before the Stock and Bond Law became effective about 39% of the railroads in Texas were in the hands of receivers. To-day there is not a mile, of the 11 300 miles in Texas, in the hands of receivers, and, with a few unimportant exceptions, no railroad has been in the hands of receivers since the law went into effect. The fact is that there has been no piece of legislation, in this or any other State of the Union during the past decade, which has been so fruitful of results and beneficent in its action, alike to the railroads and the people.

MEMOIRS OF DECEASED ME

NOTE.—Memoirs will be reproduced in the Volumes of *Transactio*
tion which will amplify the records as here printed, or correct any
forwarded to the Secretary prior to the final publication.

SELWYN MELLON TAYLOR, M. Am. Soc. C

DIED JANUARY 25TH, 1904.

Selwyn Mellon Taylor was born in Allegheny, Pe
November 5th, 1862, and perished on January 25th, 1
attempt to save human life after one of the most disast
in the mining history of the United States. His pare
Taylor and Elizabeth (Gamble) Taylor. He was mar
Mrs. Mary Nolan, formerly Miss Mary Zinn. Mrs.
two sisters are the only immediate relatives surviving h

The explosion which cost him his life occurred
Mine of the Allegheny Coal Company, near Cheswick,
Although Mr. Taylor had severed his connection with
as an engineer, almost two years before, he, immediate
of the news, hastened to the scene of the accident wit
able men in his office. None of the State mine insp
reached, and he at once assumed command of the diso
All means of ingress to the mine were destroyed, bot
been blown out, the steel head frame wrecked above th
and the man-way in the air-shaft blocked with timber
sides of the shaft; all showing that an explosion of t
which must necessarily have traversed the entire m
place at both the inlet and outlet of the ventilating air

Mr. Taylor's firm conviction, shared alike by a
present, was that all life in the mine was extinct. The
proper, being set back from the air-shaft, had escaped
and the air current entering the mine was only interru
period. After having a sheave wheel attached to the
bers of the steel head-frame below the landing-floor an
sinking bucket, Mr. Taylor decided to reverse the dir
current and attempt an entrance of the mine by way
shaft. Others volunteered for this service, and re
were made to dissuade him from entering the mine o
asthmatic condition, but to no avail. With one comp
the first descent, not intending to go beyond the shaft

There, one man was found alive and was sent up
with a request for a small number of volunteers. He s
request for the mine plan, but before it reached him h

* Memoir prepared by W. E. Fohl.

volunteers, penetrated the mine about 700 ft. At this point they were all overcome by foul air and Mr. Taylor was unable to retreat. When found he was dead, and the presence of an indentation in the forehead gave assurance that his death was instantaneous. His companions were saved.

The man whom he found alive proved to be the sole survivor of about one hundred and seventy-five in the mine at the time of the explosion; and that he did survive, the subsequent examinations of the ruins showed to be little short of miraculous. It is presumed that this survival led Mr. Taylor to think that the conclusions reached before entering the mine were at fault, and that still others might be alive.

The motives that actuate the simplest line of human conduct can but rarely be clearly and accurately defined. But quick, decisive action was characteristic of this man. His daring spirit was evidenced by every move of his professional and business career. His tender heart was manifested by a host of benefactions. And his many friends feel that these characteristics held in abeyance his judgment and led him to his untimely death.

Although Mr. Taylor's life was short, his mining career was comparatively long and eventful. He entered the office of R. L. McCully, Civil and Mining Engineer, on April 1st, 1880, was admitted by him as partner on August 15th, 1883, and assumed charge of the mining work of the firm, which he retained up to the time the partnership was dissolved, in October, 1890. This was the period of his work in the field, and it was during this time, largely, that he acquired the intimate knowledge of the bituminous coal fields of Pennsylvania and the methods of their exploitation that, later, placed him in the first rank of mining engineers of the United States. In 1886 he wrote a portion of the Annual Report of the Geological Survey of Pennsylvania, describing the mining methods in use in the bituminous coal region of Western Pennsylvania, and in 1889 was appointed by Governor Beaver, of Pennsylvania, one of the two mining engineers who are appointed every four years. to serve on the Board of Examiners for Bituminous Mine Inspectors. He also assisted with valuable counsel in the framing of the Act of 1893, revising the mine laws pertaining to the bituminous coal region.

From the spring of 1891 until the time of his death he was actively engaged in construction and consultation practice. His examinations and reports cover practically all the known bituminous coal areas of the United States, and, at the time of his death, one of his assistants, acting under his instructions, was engaged in the examination of a coal field in Southeastern Borneo for the benefit of English capitalists.

The individual mines which he developed are too numerous for mention in this memoir. His two principal monuments, in this class

of work, are the developments of the Eureka Fuel Company, in the "New Klondike" region in Fayette County, Pennsylvania, since absorbed by the United States Steel Company, and that of the Pittsburg Terminal Railroad and Coal Company, in the immediate vicinity of Pittsburg. The former consists of four mines, 1 200 beehive coke ovens, a pumping station and about 12 miles of pipe line; the latter consists of seven mines opened simultaneously for the production of steam and domestic coal. Both these developments are, in the strictest sense of the word, representative of their class. They, in common with all his work, are chiefly marked by the simplicity of the means used to attain the desired end; the combination and adaptation of old and well-tried methods and the careful laying out of work in advance based on accurate surveys. The commercial success of his work has been largely due to these factors.

At various times in Mr. Taylor's career, he received tempting offers to devote his entire time to separate organizations. These he refused, preferring the greater freedom of his general practice. In the year 1900 an opportunity was presented to acquire a very favorably located coal field, about 25 miles from Pittsburg. In this, Mr. Taylor interested some few personal friends, and with them organized the Midland Coal Company. Dock facilities were secured at Cleveland, and a rapid and systematic development of the coal field was carried forward, with the result that, at the close of the year 1902, three first-class mines and 8 miles of railroad were built and in active operation.

The situation of the property, in connection with its first-class development and the shipping facilities which had been acquired at Cleveland, gave it such value in the eyes of the Pittsburg Coal Company that the entire improvements were purchased by them at a large figure, and the entire acreage of coal was turned over to them under a lease the duration of which was forty years, the terms being so couched that it practically amounted to a sale of the entire holdings of this company to the Pittsburg Coal Company.

During the progress of these negotiations Mr. Taylor had become interested in the exploitation of a large body of Freeport coal within 12 miles of Pittsburg. The value of this property, up to this time, had been unrecognized; but a systematic exploration, by drilling and otherwise, justified Mr. Taylor in his judgment that this hitherto unknown coal field was one of the most valuable and easily accessible bodies of coal that has ever been known in the vicinity of Pittsburg. This tract was partially developed at the time of his death, and is still in the hands of his estate.

Owing to the reputation Mr. Taylor had acquired in the operating end of the coal business, by his development, successful operation and advantageous sale of the Midland Coal Company, and the brilliant opportunity which he had grasped in the above-mentioned field of

Freeport coal, overtures were made to him by prominent financial interests which eventually led to the projection of the National Coal and Coke Company, intended to operate the above-described Indianola coal property, as well as some 1 700 acres of exceptionally fine coking coal on the Monongahela River, 8 miles above Brownsville. Mr. Taylor was chosen president of this company, and his was the influence which was counted upon to interest Pittsburg capital, and also to carry its development and operation to a successful conclusion.

Mr. Taylor's career covered a period of rapid growth in the importance of the engineer's connection with bituminous coal mining, and was largely instrumental in fostering this growth. In its beginning, the engineer was a rarity in the Pittsburg region; there was simply the surveyor making maps of mine workings with the direction of which he had nothing to do. At its close, the engineer is paramount, and few moves are made without his counsel.

As is the case with all good engineers, Mr. Taylor's office was one of the schools of engineering that publish no catalogue and make no address to the general public. But a large number of young men have taken either partial or complete courses in it. Many of them are holding positions of responsibility elsewhere, and all of them hold in remembrance his valued teaching and kindly attitude toward the beginner. His own education was acquired in the ward and high schools of Pittsburg, entering the latter at a very early age. His father was a prominent member of the Allegheny County bar, and, being by nature a profound student, with mathematical attainments far above the average, rendered valuable assistance to the son in the preparatory stages of his engineering work.

Mr. Taylor was elected a Member of the American Society of Civil Engineers on October 7th, 1903. For many years he had been a prominent member of the Engineers' Society of Western Pennsylvania, and was a member of its Board of Directors at the time of his death.

Vol. XXX. MAY, 1904. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

CONTENTS.

PLATES.

Vol. XXX. MAY, 1904. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE INSTALLATION OF A PNEUMATIC PUMPING PLANT.

By Arthur H. Diamant, Jun. Am. Soc. C. E.

To be Presented September 7th, 1904.

Before proceeding with the description of the pumping plant, which is to be used in case of emergency only, the writer deems it advisable to give a brief statement as to the necessity for its installation.

As is generally known, the City of New York receives its water supply through the New Croton Aqueduct, which begins at the inlet gate-house, near the Old Croton Dam, Croton Lake, and, after reaching Shaft No. 24, on the Bronx side of Washington Bridge and near it, passes under the Harlem River to Shaft No. 25 and thence to the terminal gate-house at One Hundred and Thirty-fifth Street, near Amsterdam Avenue.

Provision has been made for emptying the aqueduct whenever necessary. The inlet gates at Croton Lake can be closed, thus preventing water from entering the aqueduct. To empty that portion between Croton Lake and Washington Bridge, there are blow-off gates

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full, will be published in *Transactions*.

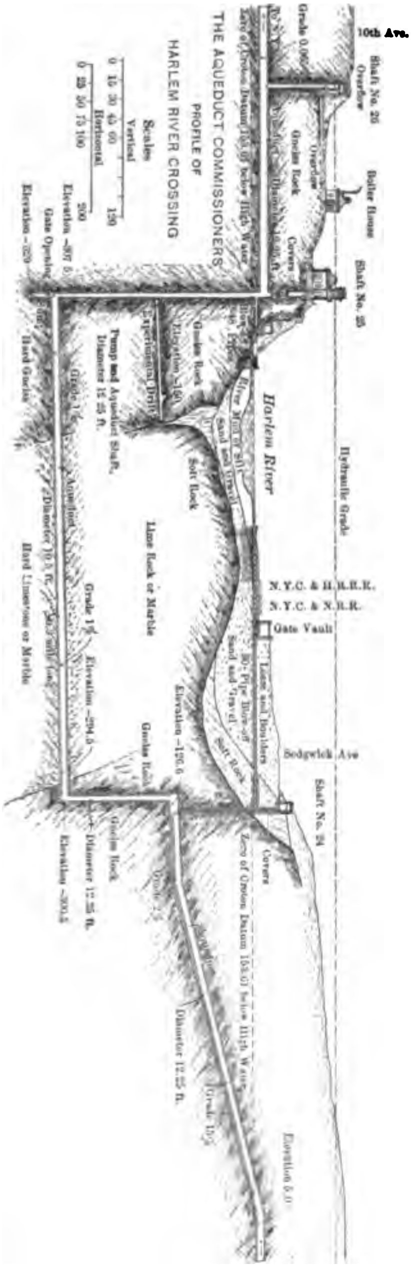

10th Ave.
Shaft No. 25
Overflow
Boiler House
Hydraulic Grade
Harlem River
N.Y.C. & H.R.R.R.
N.Y.C. & N.R.R.
Gate Vault
Sedgwick Ave
Shaft No. 24
Covers
THE AQUEDUCT COMMISSIONERS
PROFILE OF
HARLEM RIVER CROSSING
Scales
Vertical
Horizontal
Gneiss Rock
Soft Rock
Lime Rock or Marble
Experimental Drift
Pump and Aqueduct Shaft, Diameter 12.25 ft.
Hard Gneiss
Hard Limestone or Marble
Elevation −294.0
Elevation −156.6
Elevation −300.5
Diameter 12.25 ft.
Elevation 5.0

FIG. 1.

at Shaft No. 9, Pocantico; at Shaft No. 14, Ardsley; at Shaft No. 18, South Yonkers; and at Shaft No. 24, near Washington Bridge. There are also blow-off pipes on the stretch between Shaft No. 25 and the terminal gate-house, so that the aqueduct can be made to empty itself, with the exception of that portion constituting the Harlem River crossing or siphon, Fig. 1. This siphon is emptied by Shaft No. 25, the pump-shaft.

Shaft No. 25 (see Fig. 2) is really a double shaft, the northerly one being the aqueduct-shaft, and the southerly one the pump-shaft.

The aqueduct-shaft is 12.25 ft. in diameter, and, at a point about 10 ft. above high water, the aqueduct continues on its way to the terminal gate-house. The pump-shaft, also 12.25 ft. in diameter, is completely lined with iron, and contains a sump extending 21.75 ft. below the bottom of the siphon tunnel. An opening, 1 ft. 8 in. by 2 ft. 6 in., and 3 ft. below the invert of the tunnel, regulated by a gate, admits the water into the pump-shaft. This gate, being 417 ft. below the top of the shaft, is of composition metal, moving in solid composition grooves, and is designed so that no obstructions can accumulate in the frame. It is raised by a square stem, 3.5 by 3.5 in., guided every 12 ft., and contained in a 3-ft. pipe built in the masonry. This pipe also contains a ladder reaching from the top (Elevation 84.5) to the bottom (Elevation—312.75). A plan of the connection is shown in the "Section through *A B*," Plate XXII. As each shaft is under the hydraulic grade, it can be closed by a double set of manholes with covers. For the purpose of blowing off the water, each shaft is connected with a 48-in. cast-iron pipe, with two gates, and discharging into the river.

Over the pump-shaft was erected a bucket-hoist, composed of two alternating buckets, each of 1 390 gal. capacity. These were raised and lowered by a horizontal steam engine capable of emptying each in 0.5 min. Fig. 3, prepared by Mr. F. S. Cook, Engineer in Charge of the Draughting Bureau of the Aqueduct Commissioners, shows the volumes of water to be lifted in emptying the siphon. With this plant, it would have taken from 15 to 18 hr. to accomplish this task, provided the engines could have continued at the aforesaid rate. As shutting down the aqueduct would entail serious inconveniences, the present water consumption being about 296 000 000 gal. per day, the Aqueduct Commissioners deemed it necessary to install a pumping

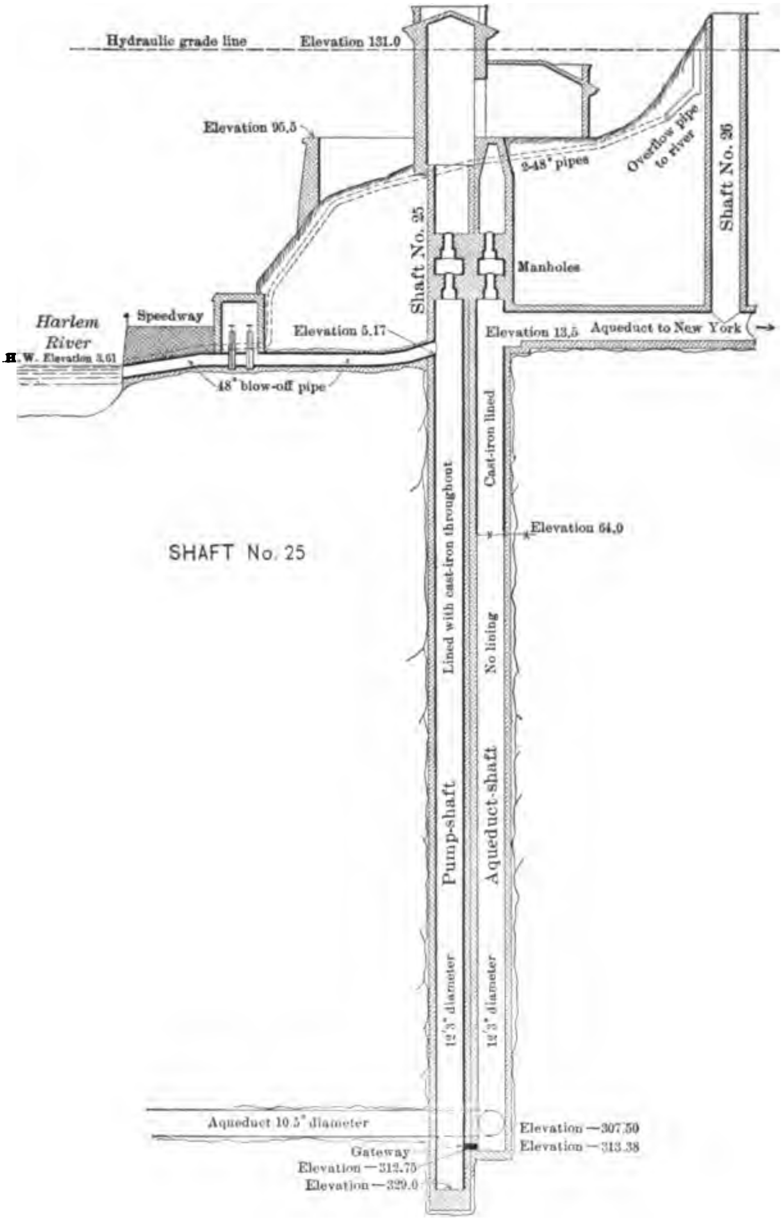

Hydraulic grade line
Elevation 131.0
Elevation 95.5
2-48" pipes
Overflow pipe to river
Shaft No. 26
Shaft No. 25
Manholes
Harlem River
H. W. Elevation 3.61
Speedway
Elevation 5.17
Elevation 13.5
Aqueduct to New York
48" blow-off pipe
Cast-iron lined
Elevation 64.0
SHAFT No. 25
Lined with cast-iron throughout
No lining
Pump-shaft
Aqueduct-shaft
12' 3" diameter
12' 3" diameter
Aqueduct 10.5' diameter
Elevation —307.50
Elevation —313.38
Gateway
Elevation —312.75
Elevation —329.0

FIG. 2.

plant which could empty the siphon in 12 hr. or less, as every hour gained would be of material advantage. Accordingly, bids were received for such a plant, and the contract was awarded to the Pneumatic Engineering Company, who proceeded to install the Harris System of pneumatic pump. The contract specified that 2 500 000 gal. be raised 337 ft. in 12 hr., with a bonus of $5 000 for every hour less than 12 hr., and a penalty for each hour longer.

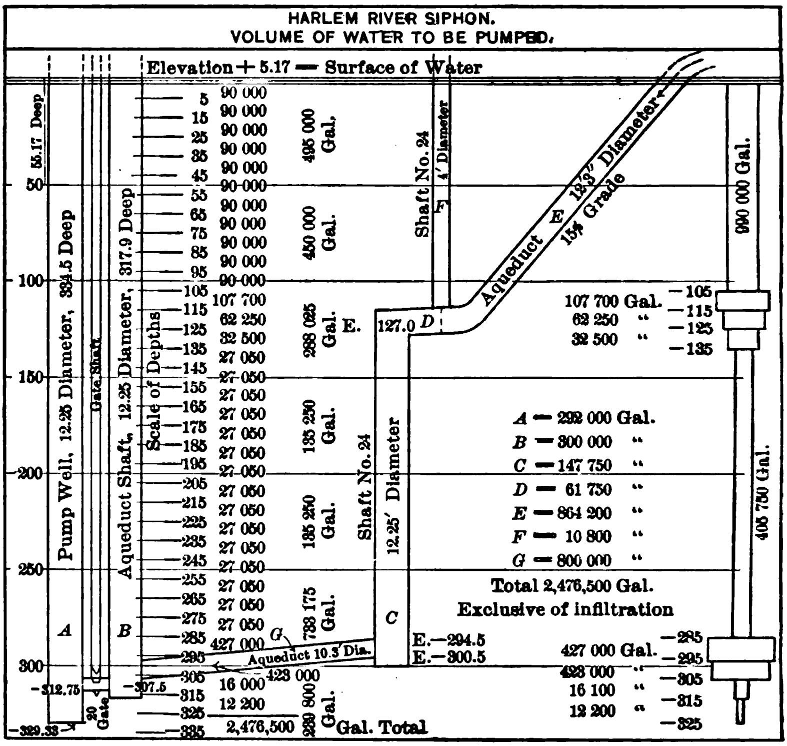
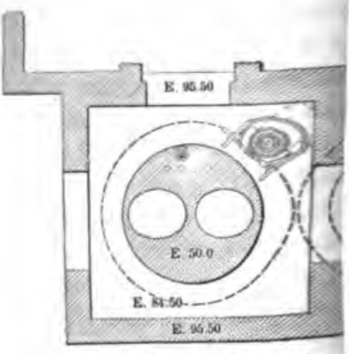


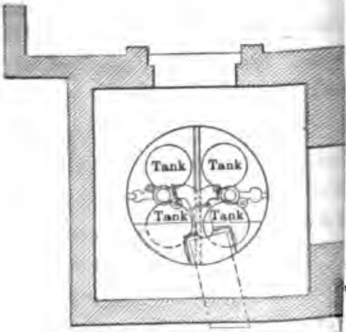
Fig. 8.

This system, briefly described, consists of a 27 by 48-in. Comstock compressor, twin-connected; the steam engine, 24 by 48-in., being the improved horizontal type, with Corliss valves. Free air, being compressed, passes through coolers, through a switch apparatus, down pipes into four water tanks working in pairs at the bottom of the pump-shaft. An auxiliary compressor supplies the necessary air for running the plant with the greatest efficiency. (See Plate XXIV.) The system is described more fully in the latter part of this paper.

PLATE XXII.
PAPERS, AM. SOC. C. E.
MAY, 1904.
DIAMANT ON
PNEUMATIC PUMPING PLANT.



SECTION THROUGH A-B



SECTION BELOW MANHOLE

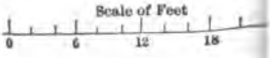
SECTIONS OF SHAFT No

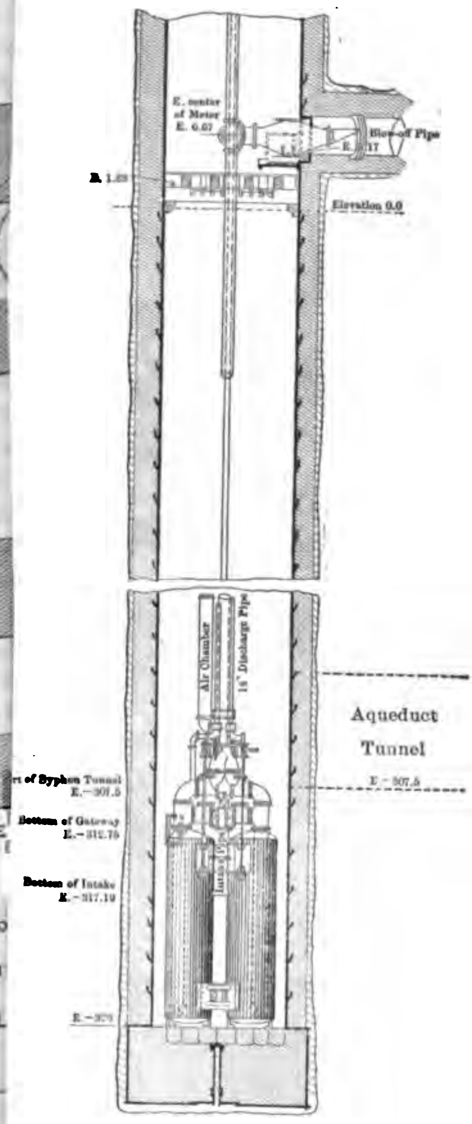
SHOWING

INSTALLATION OF TANKS AND FI

FOR

PNEUMATIC PUMPING PL





SECTION LOOKING NORTH

The installation was attended with peculiar difficulties. Leaks have developed in the pump-shaft, since its construction, keeping it full of water up to the blow-off pipe. Weir measurements taken in this pipe show a leakage of about 200 gal. per min. As there was no way of emptying the shaft and keeping it empty, all work had to be done on an erecting platform built near the blow-off pipe. A 5-in. ejector kept the water about 15 ft. below the platform.

As before stated, the shaft is below the hydraulic grade. If the gate between the aqueduct-shaft and the pump-shaft were to be opened, and the blow-off gates closed, it would be necessary to put on the covers of the manholes in the diaphragms. For this reason, the air-pipes leading down to the four water tanks (see Plate XXII) could not pass through the manhole openings, but had to pass through four holes bored through the brickwork and iron lining of the two diaphragms. As seen in the drawing, these diaphragms are each about 9 ft. thick, with a space of 6.7 ft. between them. The Rand Drill Company's Davis Calyx drill was used in making the four holes, each 9 in. in diameter, steel shot being used for the cutting surface. Cores, from 3 to 4 ft. long were taken out, showing the efficiency of drills of this style.

For the purpose of lining these holes, and making them continuous between diaphragms a 6.75-in. cast-iron pipe, with a flange at one end, was placed in each hole of the upper diaphragm, the flange resting on its upper side. A similar pipe was placed in each hole of the lower diaphragm, the flange being bolted to the iron lining of the underside thereof. A short length of pipe, of the same inside diameter and with a hub on each end, connected the two pipes of each hole. Perfectly tight joints were made with lead. The utmost care had to be taken in pouring the lead as there was a great deal of moisture in the space between the diaphragms.

While these holes were being drilled, the old bucket-hoist engines were taken apart and removed, the buckets having been taken out of the shaft previously. The old brick foundations also had to be cut away to make place for the new ones. The new foundations, both for the compressor and the steam engine, are each 9 ft. high, 8 ft. wide and 32.5 ft. long. They are composed of a 1:3:5 concrete mass finished with a 1-ft. granite coping stone over the entire top. The foundation of the auxiliary compressor is also of concrete, with granite coping stones.

The different parts of the system having arrived, th
tanks was taken into the engine-house and placed in pr
near the top of the shaft at Elevation 84.5. The second
placed also. These tanks are 17.5 ft. high and have an in
of 4 ft. 2 in. A cage, operated by a small Otis steam e
the men from the top of the shaft down to the blow-off
5.17. This cage could be shifted to pass through the n
opening as necessity required. With the four tanks, a
the elevator cage, a 36-in. water main and gate, and the li
ery for the connecting gate between the aqueduct- and
there was very little room to spare.

Fig. 1, Plate XXIII, is a front view of the tanks
assembled at Elevation 84.5, before being taken apart t
to the erecting platform. The photograph shows one
the manner in which they are connected, the intake
10-in. check-valves admitting water into the tanks, the 14
pipes with 10-in. check-valves opening outward, the 5
and the I-beams and hangers for lowering the tanks.
pipe passes into each tank within about 6 in. of the bott
this point guiding the water from the tank into the d
(see Plate XXII). Near the top of the inlet pipe is a ca
which is to slide along the old bucket-guides in the sh
similar to this are on the plates connecting the tanks ne
and also on the plates in the back of the tanks. The
hangers to which the wire cables of the lowering
attached can be seen near the extreme top of the photog

On top of the Y, connecting the discharge pipes of t
a T was placed, to which, by means of an elbow, an air
fastened to prevent water ram. A ⅜-in. pipe, with a chec
from this elbow to the top of the shaft, being used to
chamber. At this point, also, the discharge pipe and th
were fitted with swivel joints, so that, even if the tank
perfectly level on the bottom, the pipes could be carried
by means of these joints, which were perfectly tight.

The 14-in. discharge pipes are rolled-steel tubes
flanges. These were shrunk on the tubes, and the end
were upset. The pipes were delivered in this conditio
upset ends projected from an ⅛ to ½ in. beyond the faces

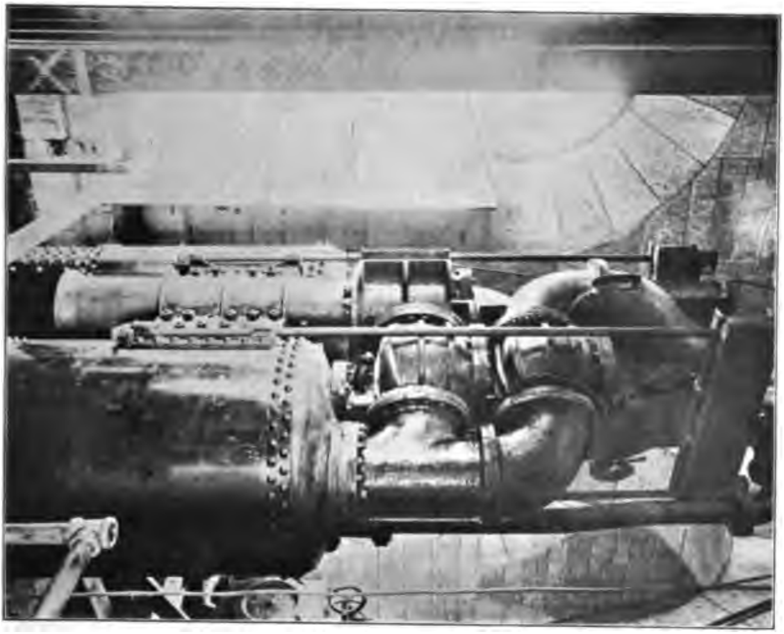


Fig. 1.—Front View of Tanks and Fittings for Pneumatic Pumping Plant.

Fig. 2.—Automatic Switch and Connections for Pneumatic Pumping Plant.

this part had to be removed, otherwise no tight joints could have been made. To return the pipes to the foundry would have caused the loss of too much time, therefore a lathe was rigged up outside of the engine-room. Sand was strewn over the space to be used, some iron-grating floor-plates from the shaft-house were embedded in the sand, and several pieces of the coping stone of the old engine foundation were placed on top of the plates. Two 15-in. I-beams, 20 ft. long, with a space of about 4 in. between them, were laid on top of the stones and fastened firmly by steel rods passing down to the grating plates. The I-beams were leveled carefully, and the 14-in. pipes, being laid on top, were thus also level. The pipes were held fast by a V-shaped clamp at each end. A chuck holding the cutting tool was geared to a shaft which was revolved by being belted to a small vertical steam engine. The tool was fed automatically into the flange to be faced by means of a star wheel which, at each revolution of the chuck, would strike one of its prongs against a projecting board, thus causing the tool to cut deeper. This apparatus proved to be very efficient, as the faces of the flanges were made absolutely at right angles to the axis of the pipe, thus ensuring a perfectly straight column when the lengths were bolted together. There were thirty-two pieces to be faced on each end, and the entire work was completed in 11 days.

While this was being done, men were engaged in placing an erecting platform, just below the blow-off. This consisted of brackets fastened to the east and west sides of the shafts with bolts let into the iron lining. On these brackets was placed a 15-in. I-beam, which was bolted down. Resting upon this beam, and also upon brackets fastened to the north and south sides of the shaft, were placed 12-in. timbers, over which a 3-in. plank flooring was fastened. All drilling for stud-bolts was done with a pneumatic drill, the air being supplied by a small Rand Drill Company's compressor on top of the shaft.

Just before the erecting platform was completed, there occurred the only accident during the entire installation. Fortunately, this was attended with no serious results. In order to lower the tanks, it was necessary to remove the catch-basin into which the buckets of the old system discharged.

The bottom plate is shaped like a segment of a circle, with a chord

of 11 ft. 6 in., and a rise of 3 ft. 10 in., the radius of the arc being 6 ft. 1½ in. The weight of the plate was about 2 000 lb. Two 8 by 12-in. holes had been cut into it some years ago. Two workmen were on top of the plate passing a chain through one of the holes, when it slipped from its bearings, tipped over, and dropped to the bottom, a distance of 333 ft. The men were thrown into the water, but, with the exception of some bruises, were not injured seriously.

Before lowering the tanks, this plate had to be recovered. Accordingly, the writer, with an assistant, sounded every foot of the bottom of the shaft with a steel tape and lead weight, and was fortunate enough to locate one of the 8 by 12-in. holes. A chain with a hook at the end was fastened to the elevator cable, lowered to the bottom, and guided from the erecting platform by a ribbon tape. The hole, located by previous soundings, was again found, and, after two or three trials, the plate was hoisted to the surface. A small corner broken off was the only damage the plate sustained.

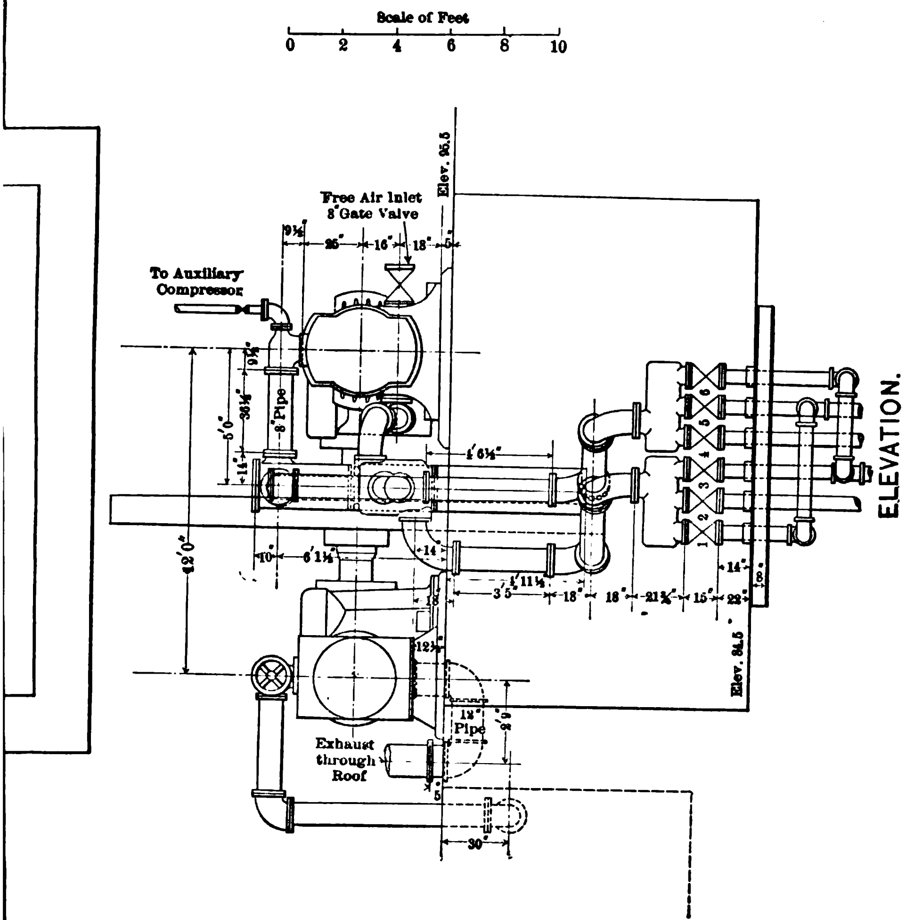
As the soundings indicated some silt at the bottom of the shaft, sixty bags of sand were dumped into the shaft, the bottom being thus fairly leveled.

The first pair of tanks and fittings, which had been assembled at Elevation 84.5, was now taken apart, preparatory to being lowered to the erecting platform. The elevator cage was hoisted out of the shaft, so that its cable could be used. Each tank was first lowered to the top of the first diaphragm with a block and fall. The elevator cable was then attached and the tank was lowered to the erecting platform. The tank was hung with such exactness that it passed through the manhole without binding, although there was only about ¼ in. clearance. The T's and Y's, and other parts having been lowered, the first pair of tanks was again assembled, and placed in the exact position in which they would have to be lowered to the bottom.

The first pair of tanks being out of the way, the hydraulic lowering apparatus was set up in the south half of the shaft at Elevation 84.5 (see Plate XXII). This apparatus consists of a cylinder with a plunger having a stroke of about 21 ft., a balanced elevator-valve and pressure pump, two A-frames on top of the upper diaphragm and two on the erecting platform. In the timber bents, 10 by 10-in. beams were used. Plow-steel wire cables were used, and were fitted with

PLATE XXIV.
PAPERS, AM. SOC. C. E.
MAY, 1904.
DIAMANT ON
PNEUMATIC PUMPING PLANT.

ENGINE-ROOM AND PUMP SHAFT.



sockets at each end. Their breaking strain was 98 tons. A 60-ft. length of cable reached from the lifting I-beams of the plunger to the holding I-beams above the tanks, the plunger being about 1 ft. from the top of its stroke. Two cables were used for each pair of tanks. The plunger was now raised as high as it could go, the tanks thus being raised about 1 ft., and the planks and beams on which they had been resting were removed. The water in the hydraulic cylinder having been allowed to exhaust, the tanks were lowered 20 ft. The A-frame on the upper diaphragm had been placed in position, and the sockets of the 60-ft. cables rested on clamps which were now bolted on. These clamps in turn rested on I-beams on top of the bents. While the whole weight rested on these A-frames, the pins, which held the sockets of the cables to the lowering I-beams of the plunger, were removed, the plunger was again raised to near the top of its stroke, and the longer A-frames on the erecting platform were placed in position. A 20-ft. length was added to each cable, a length of 14-in. pipe to the discharge pipe, a length of 5-in. pipe to each of the air-pipes, and a length of ⅜-in. pipe to each of the charging pipes of the air chambers. Each joint was tested under an air pressure of 150 lb., as were also the tanks and valves before lowering, to insure perfect tightness of all joints. The load was now raised slightly, the clamps removed, and the tanks lowered 20 ft. The procedure being the same, the tanks were lowered another 20 ft., this time, however, the clamps rested on the I-beams of the lower A-frames. The three 20-ft. lengths of cable were now taken out and replaced by a 60-ft. length, and the cycle again started. In this manner the first pair of tanks was safely lowered to the bottom of the shaft, a depth of 332 ft. Pipe-guides or stays were fastened to the pipes every 60 ft., the ends of the stays sliding along the old bucket-guides. The total weight lowered was estimated at about 40 tons. The elevator cage was now shifted to the other side of the shaft, as was also the hydraulic lift, and the second pair of tanks was lowered in the same manner as the first. All parts before going down were painted both outside and inside with two coats of "Nobrac" paint.

The top of the discharge pipe of the second pair of tanks was about 4 in. above that of the first pair. Short lengths of discharge pipe added to each brought them to the same level. To this discharge pipe was added a T-piece. A Y connected the T-pieces, and a 20-in. goose-

neck, of galvanized-iron pipe was bolted to the Y. This pipe discharged into a catch-basin at the entrance of the blow-off, the bottom plate being the same one that fell to the bottom of the shaft, the sides being smaller than those of the old one. Cover-plates were bolted to the top of the two T-pieces. The four 5-in. air-pipes were now carried up to Elevation 84.5. Glands, through which these pipes passed, were bolted to the flanges of the iron lining of the holes through the upper diaphragm, so that, if the covers of the manholes were put on, the water could not pass between the air-pipes and the lining of the holes. When the shaft was built, a 4-in. pipe from the bottom of the lower diaphragm to a point 1 or 2 ft. above the hydraulic grade, served as an air-vent when the manhole covers were on. This pipe had been removed, above the upper diaphragm, and the two $\frac{3}{8}$-in. pipes were carried through this 4-in. opening to the top. This 4-in pipe was afterward replaced.

At Elevation 84.5 the four 5-in. air-pipes were connected with two manifolds, and from each of the manifolds an 8-in. air-pipe led to the switch. By means of these manifolds, any two tanks could be cut out of service and the pumping done with the other two. (See elevation of general plan, on Plate XXIV.) The two $\frac{3}{8}$-in. pipes from the air chambers were connected by a Y, and led to the 8-in. air-pipe from the after-coolers to the switch. A $\frac{3}{8}$-in. pipe from the same point, with a pin-valve to allow air to leak into it, was hung down into the shaft, within 6 ft. of the bottom, passing through the 4-in. opening through the diaphragms. This shows the pumping level and the pressure due to the head of water in the shaft. An 8-in. pipe carries the return air from the switch to the compressor on the side opposite the free-air valve.

The switch consists of a plunger, with a stroke of $6\frac{5}{8}$ in., operated by a piston moving in a smaller cylinder. The air is introduced into this smaller cylinder by a valve which depends for its action on a piston in a small cylinder, which, in turn, is caused to move by the action of a disc-valve. (See Fig. 2, Plate XXIII.) The disc or diaphragm is 6 in. in diameter, with a movement of $\frac{3}{32}$ in., and consists of two thin sheets of bronze and one sheet of steel. A $\frac{3}{8}$-in. pipe conveys the return air from a point near the top of the cylinder of the plunger to one side of the disc-valve, and the $\frac{3}{8}$-in. pipe, which shows the pumping level and pressure due to the head of water, leads to the other side

of this valve. This latter ⅜-in. pipe, connected with the 8-in. pipe from the after-coolers to the switch, receives air through a pin-valve, and is also piped to a gauge on the gauge-board, so that the pumping level and the pressure due to the head of the water can be seen at a glance. A small reservoir on this line gives a constant supply of air. The small, return air-pipe is also piped to a gauge, showing the return pressures. The difference between the pressure due to the head of the water in the shaft, which for the same levels is constant, and the return pressure (which is varying constantly, and drops to zero when the switch acts), causes the disc-valve to move. As the operation of the switch requires an air pressure of only about 50 to 60 lb. per sq. in., a ⅜-in. pipe from the 8-in. compressed-air pipe conveys the air through a reducing valve to the cylinder on top of the plunger, and to the piston of the small cylinder operated by the disc-valve. A reservoir on this line also ensures constant pressure. This ⅜-in. pipe also leads to a dial on the gauge-board, showing the pressures required to operate the switch. The disc-valve moving, due to the difference between the pressure caused by the head of the water in the shaft and the return pressure, allows air to enter the small cylinder above it, the piston moves, the valve controlled by this piston motion allows air to enter above or below the piston in the cylinder above the plunger, the plunger acts and the air is sent alternately from one 8-in. air-pipe into the other, one of these 8-in. pipes always serving to return the air through the switch to the compressor. (See Plate XXIV.) Provision is also made for operating the actuating valve by hand.

The auxiliary compressor was set up, the large compressor and engine were adjusted, the piping was completed between the auxiliary compressor, the large compressor, the switch after-coolers, and the receiver, and the plant was ready for operation. Before pumping, all joints were tested as to tightness.

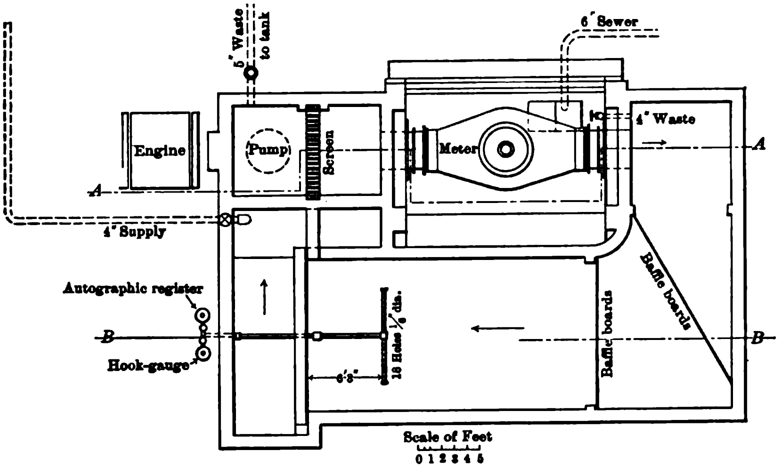
The action of the plant is as follows: The large compressor is first started; the exhaust valve being closed, it requires about 312 revolutions of the fly-wheel to charge the system, the free air being compressed to 150 lb. per sq. in. The free-air valve is now closed and the switch thrown over by hand. The compressed air passes from the compressor through the two after-coolers, into a receiver supplied with a safety valve, and also through the switch through one of the 8-in. pipes, through its manifold into the 5-in. air-pipes and into one pair of tanks.

The air entering this pair of tanks forces the water through the discharge pipes and empties the tanks. As soon as this occurs, the return pressure from the other pair of tanks being less than the pressure due to the head of the water in the shaft, the actuating valve of the switch acts, the plunger moves, compressed air enters these tanks, while the air from the other pair is returning through the switch into the compressor to be used over again, and so on. A cycle consists of the number of revolutions of the fly-wheel necessary for the compressor to empty one pair of tanks to the point of starting to empty the other pair. The number of revolutions per cycle varies for different plumbing levels, but is constant for the same level. If there are too many revolutions in charging the machine, or if there are too many revolutions per cycle, the air follows the water through the discharge pipes, and thus the system loses the air, necessitating the opening of the free-air valve of the compressor and recharging. After the plant has been working, a certain amount of air is lost, and in order to keep up the proper number of revolutions per cycle the auxiliary compressor is started, and furnishes the air to keep the system working efficiently.

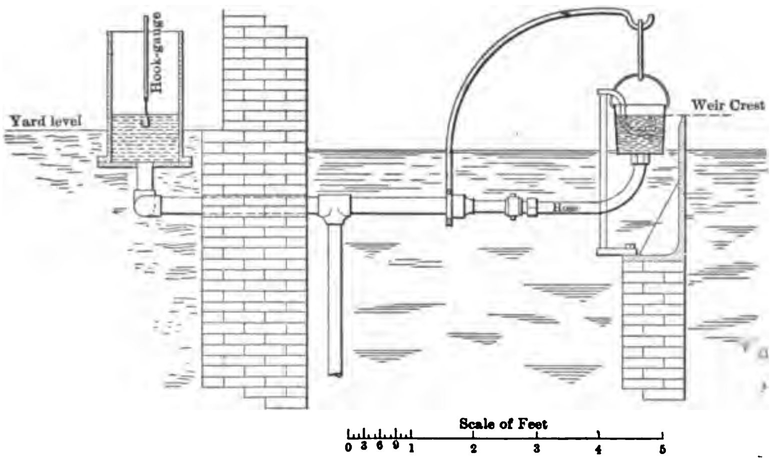
Before the final test, many trials were run. Indicator diagrams of the Corliss engine were taken, and adjustments were made. The goose-neck discharge pipe was removed, and a 20-in. Gem meter placed in its stead. The cover-plates were taken off the T's, and a 20-ft. length of 14-in. galvanized-iron pipe was added to each, so that no air would pass through the meter, but would escape through these pipes. (See Plate XXIV.) Many other changes took place before the proper number of revolutions per cycle for different pumping levels was determined.

The 20-in. Gem meter consists of a system of helicoids formed around a vertical central hub, revolving in a cylinder slightly greater in length, and having a diameter just large enough to receive it. A screen at the lower end of this cylinder serves to keep large objects from entering the meter. The axle of the hub is geared to the meter register, which contains six figures and reads thousands of gallons.

As it was necessary to test the accuracy of this meter, before using it, to determine the efficiency of the pneumatic pumping plant, F. W. Watkins, M. Am. Soc. C. E., Division Engineer of the Aqueduct Commissioners Engineering Department, assisted by the writer, made a



TESTING PLANT FOR LARGE METERS
FIG 4.



CHECKING HOOK OF LARGE WATER METER TESTING PLANT
FIG. 5.

test of the meter at the testing plant of the National Meter Company, in South Brooklyn.

The test consisted of a comparison of the meter register records with weir measurements of the same volume of water. The water to be measured was elevated by a centrifugal pump operated by a Nash gas engine to a height which gave a head sufficient to force the desired amount through the meter. The water passed from the pump, through a screen, into a small forebay, thence through the meter into the L-shaped weir chamber. The base of the L is about 8 ft. long and 8 ft. wide, and the long side, constituting the main weir chamber, is 33 ft. long, 12 ft. wide and 6 ft. deep below the level of the weir crest. Baffle boards, placed in the angle of the L, serve to break up any eddies which may form. The water flowing over the weir drops into the pump-well, and the cycle is again started. (See Fig. 4. Figs. 4 and 5 were furnished by John H. Norris, M. Am. Soc. M. E., Assistant Engineer, National Meter Company, whom the writer takes this opportunity of thanking for his courtesies during the test.)

The weir notch is of cast-iron plates, the plates forming the sides of the notch being adjustable, so that any length of weir, up to 8 ft., can be obtained. The crest was formed by beveling the down-stream face at an angle of 45°, leaving a truly planed edge $\frac{1}{4}$ in. thick, the vertical sides having a similar bevel. The distance from the bottom of the weir chamber to the crest is 6 ft.

The apparatus for measuring the head on the weir consists of two 12-in. cast-iron pipes set on end just outside of the catch-basin, one containing a float for the autographic record, the other the movable hook-gauge.

These pipes are connected by a 2-in. pipe from which a 2-in. pipe leads through the wall of the catch-basin, with a valve at the other end. Another 2-in. pipe runs from this pipe to the bottom of the catch-basin, makes a right-angle bend, thence, parallel to and about 6 in. above the floor, it runs into the weir chamber and connects with a 2-in. pipe at right angles to it, parallel to the weir crest, and about 6.25 ft. from the weir plate. This latter pipe was perforated with eighteen holes, each $\frac{3}{16}$ in. in diameter. (See Fig. 4.)

Before starting the test, the relation of the hook-gauge and the autographic float-gauge to the weir crest was determined as follows: A fixed hook-gauge was fastened a few inches in front of the weir,

and, by a spirit level, its point was adjusted exactly to the elevation of the weir crest. (See Fig. 5.) A bucket, with a rubber hose attached to the bottom, was hung over this fixed hook-gauge, the other end of the hose being attached to the 2-in. pipe leading to the movable hook-gauge, and to the autographic record. Water was poured into the bucket until the surface just covered the point of the fixed hook, when the water rose to the same elevation in the two 12-in. cast-iron pipes. The zero of the movable hook-gauge and the fixed pencil of the autographic gauge were now adjusted to correspond. The autographic gauge consists of a zinc float carrying a brass rod, to which a pencil is attached. Its point presses against a paper wrapped around a wooden cylinder revolving once an hour by clockwork. Another pencil, attached to the frame holding the drum, marks a line corresponding to the elevation of the weir crest, so that the actual heads of water flowing over the weir can be seen at a glance.

These preliminaries being over, the bucket was removed and the test begun. The weir opening was measured by a standard steel rule and was 4.2475 ft. Sufficient water from the city main was allowed to run into the catch-basin, the pump was started, and the water began to circulate. In order that the wind might not affect the test, the weir chamber was covered with boards.

The Francis formula, with Hamilton Smith's correction, in the form of

$$Q = 3.29\left(L - \frac{H}{10}\right) H^{\frac{3}{2}},$$

was used to calculate the quantity of water passing over the weir. In this formula

Q represents cubic feet of water per second;
L represents the length of the weir in feet;
H represents the head in feet.

The velocity of approach was so small that it did not enter the calculation at all. The heads scaled from the autographic record checked very closely with the hook-gauge record. Table No. 1 is a summary of the tests, and is taken from the report of Major Watkins to William R. Hill, M. Am. Soc. C. E., then Chief Engineer of the Aqueduct Commission.

TABLE No. 1.—SUMMARY OF METER TESTS.

Test.	Head, in Feet.	Gallons per minute.		Percentage, meter to weir.
		Meter.	Weir.	
First	0.296	1 002	1 003	99.90
Second	0.491	2 140	2 133	100.33
Third	0.603	2 905	2 895	100.34

These tests proved the meter to be very accurate and consistent for different heads, and it was recommended by Major Watkins as the standard measure for the pneumatic pumping plant at Shaft No. 25.

As it was impossible at that time to shut down the aqueduct. so that the siphon could be actually emptied, it was decided to pump at different water levels in the pump shaft. The water was first pumped out through the blow-off pipe until its surface was about 50 ft. below it, when the gate was closed far enough to allow only the leakage into the shaft to pass through, the remaining water running back into the shaft. After pumping at this level for an hour, the gate was opened and the water pumped down to 125 ft. below the blow-off, when the gate was closed down again to allow only the leakage to run off. In like manner the plant was tested for levels 175, 225 and 300 ft. below the blow-off.

The average volumes pumped per minute, as indicated by the Gem meter, were as follows:

At 88 ft. below the blow-off..........6 290 gal. per min.
" 125 " " " " " ....6 020 " " "
" 175 " " " " " ....5 220 " " "
" 230 " " " " " ....4 286 " " "
" 298 " " " " " ....2 180 " " "

A table showing the details of these tests has been filed for reference in the Library of the Society.

It had also been agreed to run an endurance test of 12 hr., pumping at a level about 175 ft. below the blow-off, but, owing to the dismantling of several boilers, sufficient steam could not be obtained and the test was postponed for several weeks. In the meantime, the machinery was overhauled; a revolution counter was placed on the

auxiliary compressor, and a small pump lubricator attached to the switch-plunger cylinder. A small steam pump was also connected with the line of water pipe leading from the 36-in. pipe to the water jackets on the large and auxiliary compressors and also to the after-coolers, as previous to this there was not sufficient water to keep the air properly cooled.

In conclusion, the writer wishes to express his thanks to Mr. J. Waldo Smith, Chief Engineer, and to Major F. W. Watkins, Division Engineer, for their kind interest in the preparation of this paper.

Vol. XXX. MAY, 1904. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

SOME NOTES ON THE CREEPING OF RAILS.

By Samuel Tobias Wagner, M. Am. Soc. C. E.

To be Presented September 7th, 1904.

In January, 1903, the writer commenced a series of observations, for the Philadelphia and Reading Railway Company, upon the creeping of rails at a number of points on the Company's lines. This work was undertaken in order that certain questions propounded by Dr. P. H. Dudley, Reporter for America, on "Ways and Works, Rails for Lines with Fast Trains," for the Fifth International Railway Congress, could be answered as intelligently as possible. The writer is enabled to present these data to the Society by the courtesy of Theodore Voorhees and William Hunter, Members, Am. Soc. C. E., with the hope that they will prove of interest and will elicit discussion on a very interesting subject to the railroad engineer.

Object of the Investigation.

Among the questions, in the circular letter of Dr. Dudley above referred to, were ten under the heading "Methods for preventing creeping, especially on double-track lines and on steep gradients,"

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full will be published in *Transactions*.

and the investigations were made because there were no records of rail movements from which even ordinary answers could be obtained. That there is a longitudinal movement of the rails. under certain conditions, is a firmly established fact, but how it was influenced by conditions of roadbed, weight of rail, grades, traffic, etc., remained to be determined. The results of the observations, as will be shown later, are too few to establish firmly any laws, but it is hoped that what has been done and is here presented will make one link in a chain which ultimately may allow certain definite principles to be laid down. The observations were not undertaken to ascertain the best method of

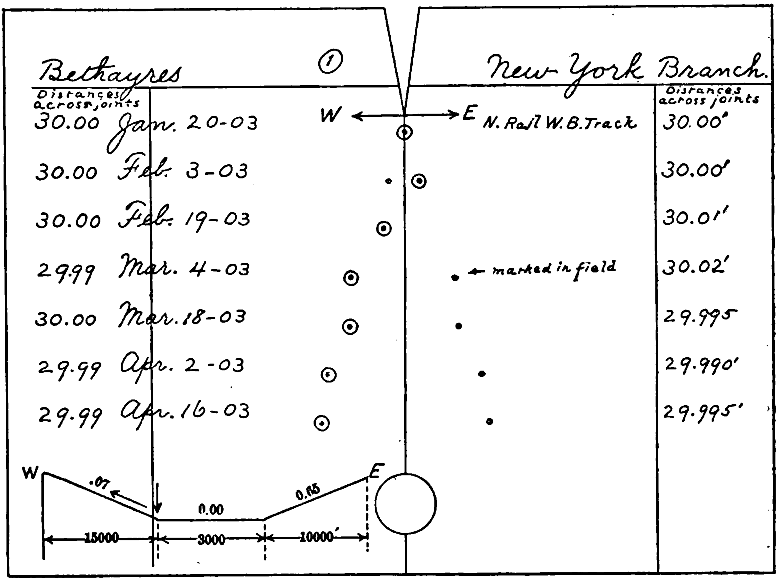


FIG. 1.

preventing the creeping of rails, and therefore no discussion of this interesting feature is presented.

Method of making the Observations.

In order to make the measurements as carefully as possible, two stakes, 3 by 1¾ in., and 24 in. long, were driven level with the ground about 15 or 20 ft. from the nearest rail, where possible, and located at right angles to the track, if on a tangent, or on a radial line, if on a curve. They were placed so as to be approximately in the center of two rails and miss any joints. In the top of each stake an ordinary

surveyor's tack, with a depressed center, was driven. A transit was set up over one stake and sighted on the other, and points on the line were marked on the flange of each rail with a fine center-punch. All observations were made on double-track lines, and, on the tops of the two outside rails, similar marks were made.

From these marks on the outside rails measurements of exactly 30 ft. were made to the right and left, spanning a joint in each direction, and marked with the same center-punch. These points were placed in order to try and determine whether there was any movement in the joints due to expansion or contraction, or whether, when there was a longitudinal movement, it was transmitted through the joints to the next rail. The division superintendents were requested to notify the repairmen to avoid these joints as much as possible during the continuance of the observations. It is safe to say that no disturbance of the track took place during the time the observations were being made, unless noted in the tables.

A card, similar to that shown in Fig. 1, was prepared for each rail. A center line was drawn across the card terminating at the top in a regular-shaped V. The card was then placed on the flange of the rail, a sharp-pointed pencil was placed in the center-punch mark and the card oriented by the observer at the transit. The card was then placed firmly against the rail, the pencil removed, and a point marked on the card on the line given by the observer at the transit which had been previously set on one stake and sighted on the other. Upon returning to the office this point was transferred to the opposite side of the center line, as in its first position it indicated a reverse movement of the rail.

On the cards prepared for the outside rails, the distances across the joints were recorded, marked "*X*" when measured to the left, and "*Y*" when measured to the right. Temperature observations were also made and recorded, the thermometer having been exposed to the direct rays of the sun while the observations were being made. The length of time consumed in making the observations approximated about 15 min., depending upon the difficulty in finding the punch marks obscured by grease, dust, dirt, snow, ice, etc., on the rail. The work required the services of two men, one with the transit and the other handling the cards on the rails.

This method was decided upon after some discussion, and adopted

because it seemed to eliminate errors in making the notes, and at the same time showed on the cards the actual movements, without the necessity of measuring small distances, with the probabilities of errors in reading.

In most cases the observations were made at intervals of about two weeks with the exceptions noted in the records. On the Atlantic City Railroad, the intervals were a month apart, on account of the extremely slow movement of the rails.

The center-punch marks on the tops of the rails on some of the branches had to be constantly remarked, especially where there was heavy traffic and heavy grades combined, as on the Frackville Branch, and on the Mahanoy and Shamokin Branch. Several observations were lost in this manner.

Description of the Points Selected.

The plan for making the observations contemplated the following outline, with special reference to grades and traffic:

1.—Lines having the greatest high speed, light tonnage and lightest grades;

2.—Lines having high speed, heavy tonnage and light grades;

3.—Lines having average speed, average tonnage and moderate grades;

4.—Lines having slow speed, heavy traffic and heavy grades.

In most cases inquiry was made before the points were selected, to ascertain where creeping had been noticed, with a general purpose of selecting the points so that they would fulfill most of the requirements.

The following are detailed, and concise descriptions of the features of interest on the branch roads on which the points were selected.

Atlantic City Railroad.—This road is a double-track line, extending from Kaigns Point, Camden, N. J., to Atlantic City, N. J., and carries moderate traffic, compared with the other lines considered, but most of the passenger traffic is carried at high express speeds, the schedule of the so-called 60-min. trains being 50 min. from Camden to Atlantic City, a distance of 55.5 miles. The freight business is not heavy. The alignment throughout is very good, and the grades, with one exception, between Clementon and Albion, very light.

At the points marked Clementon and Albion both tracks are laid

with 90-lb. rails of the section recommended by the American Society of Civil Engineers, and have stone ballast.

At Pleasantville and Farmington the south-bound track was laid with 90-lb. rails and stone ballast and the north-bound track with 80-lb. rails and cinder ballast. At Pleasantville the point is on an embankment over the salt marsh of the Atlantic City meadows.

The point at Clementon is in a sump between two of the heaviest grades on the line. At Albion the point was selected as being at the bottom of the heaviest single grade.

On account of the high-speed traffic, the physical condition of the road is very good.

New York Branch.—This branch is a double- and in some cases a three- track line extending from Wayne Junction, Philadelphia, to Bound Brook, N. J., a distance of 54.9 miles. A very heavy traffic is carried, the passenger business being carried at high speeds. There are eight passenger trains daily in each direction, making the trip from Wayne Junction to Bound Brook in 58 min., while five other trains each way daily make the same run in 66 min. The line is equipped throughout with 90-lb. rails and stone ballast. The maximum grade is 0.7 per cent.

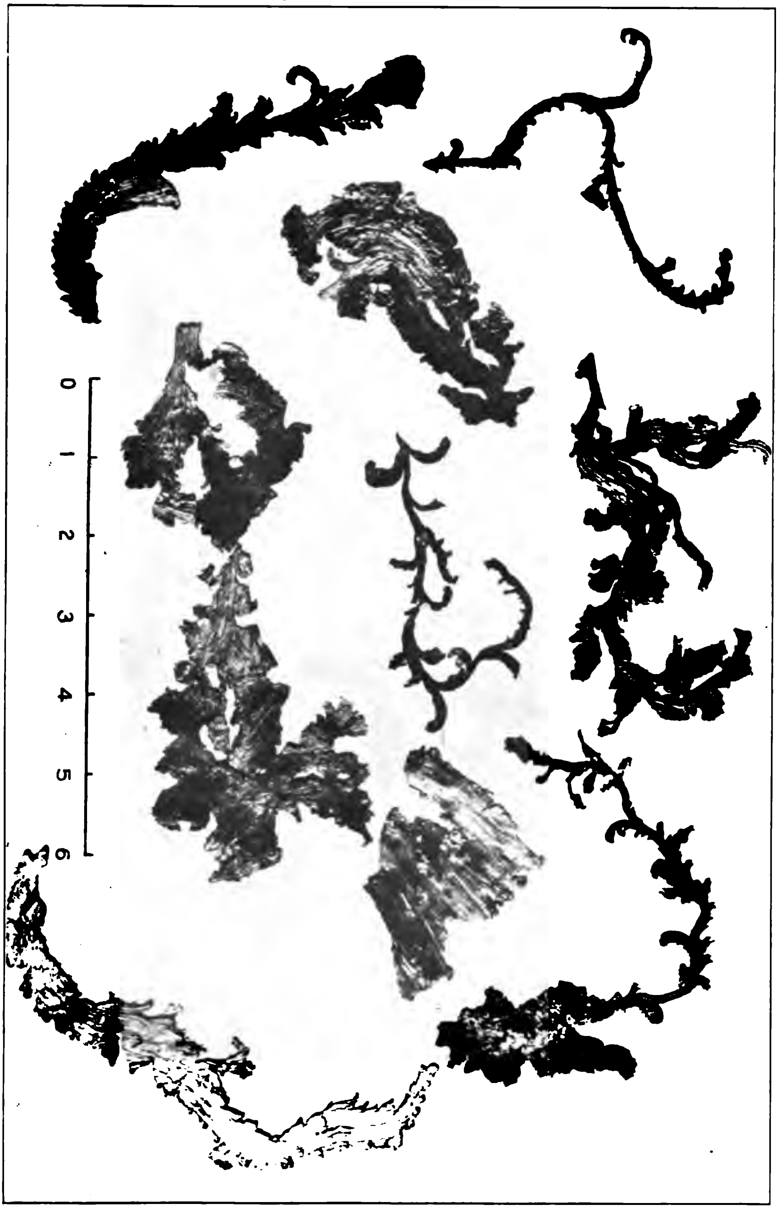
At Bethayres the point is located at the foot of a 0.7% grade which is about 15 000 ft. long from the west. There is a level stretch of about 3 000 ft. and then a grade of 0.65%, about 10 000 ft. long, to the east. The point is on an embankment over low swampy ground.

Philmont is at the top of the 0.65% grade referred to at Bethayres, and is in a good dry cut.

Neshaminy Falls is at the foot of another 0.65% grade which runs out level. It is a point where the maximum speed is attained by express trains. It is on an embankment but on a hard substratum.

Hopewell is in a cut on a rather soft substratum, and is approached from the west on a level tangent about 6 000 ft. long, and from the east at the foot of a 0.7% grade about 4 000 ft. long.

Bethlehem Branch.—This branch leaves the New York Branch at Jenkintown and extends to Bethlehem, Pa., a distance of 46.0 miles. It is double-tracked throughout. The grades are heavier than on the New York line, the maximum being 1.13 per cent. The traffic is not as heavy nor the speed as fast as on either of the lines already mentioned. As a general thing, also, the weight of the rail is 80 lb. Rail



FRAGMENTS OF STEEL FROM LOCOMOTIVE TIRES.
The scale on the photograph represents inches.

creeping was reported to have been noticed near a number of the points selected.

Quakertown is on a level stretch of track slightly beyond the foot of a 0.38% grade. The south-bound rail is 90-lb. and the north-bound 80-lb. The ballast is of furnace slag.

North Wales is on a 30-min. curve near the summit of a long 1.13% grade. It is in a rock cut. The track is laid with 80-lb. rails, and the ballast is furnace slag.

Gwynedd is on a tangent at the foot of a 1.13% grade about 11 000 ft. long. The rails are 80-lb., and the ballast is furnace slag.

Oreland is near the foot of a 0.8% grade about 8 000 ft. long. The rails and ballast are the same as at Gwynedd.

Frackville Branch.—This branch extends from the top of the inclined plane at Frackville, Pa., to a point near Pottsville, Pa., and carries a very heavy south-bound traffic of loaded coal cars down a grade of 3.3% for a distance of 3.8 miles. The north-bound traffic is practically all empty coal cars. Nearly all the coal from the Shamokin Coal Fields, to tidewater at Philadelphia, is brought over the Mahanoy and Shamokin Branch to Mahanoy Plane. There it is pulled up an inclined plane with stationary engines to Frackville, whence it passes down the other side of the mountain, as described.

The head of the grade is at the top of the mountain, not far from the summit, and Broad Mountain is at the foot of the 3.3% grade.

The rails are 90-lb. on both tracks, and the ballast is of engine cinders. As there is absolutely no fast traffic, and only a few passenger trains each way daily, the condition of the roadbed is not kept up to the same standard as on the other branches already mentioned. The line formerly was laid with 80-lb. rails, the 90-lb. rails being put down only recently. Intermediate angle splices were put on the 80-lb. rails at points on the south-bound track where the creeping was greatest, but, at the time the observations were made, they had not been put on the 90-lb. rails at the points of observation. They are now on. These are fastened to the rails with old splice-bars with two bolts, and spiked to the ties through the slots.

Mahanoy and Shamokin Branch.—This is part of the Shamokin Division, the points selected being on the south side of Locust Mountain, on the heaviest grades of the line. This is on the main line from Tamaqua to Shamokin, Pa. The grade is 2.5% and the traffic heavy,

but at moderate speeds on account of the grades. The heaviest traffic, which is made up largely of the coal from the Shamokin District, is on the south-bound track. On the south-bound track, 90-lb. rails are used, and 80-lb. on the north-bound. The ballast is of engine cinders.

Locust Summit is at the top of the grade, and is in a cut which is rather wet. Locust Dale Junction is at the foot of the same grade.

The wear of the rail is very marked on the south-bound track, on account of the heavy braking required on loaded trains. This braking is very hard on the brake-shoes and tires of the engines, as is shown by the pieces of steel removed from the engine tires, and found along the track. Photographs of some of these are shown in Plate XXV. Similar pieces are found on the south-bound track of the Frackville Branch.

The Observations.

The results of the observations are shown in Tables Nos. 1 to 4, and in Plates XXVI to XXIX, in which are given all the conditions of the location and traffic, as well as the rail movements. The alignment, character of the roadbed, manner in which the joints are spiked to the ties, cut or fill, traffic, detailed location of the points selected, with reference to the joints and the grades, are given in order to aid in an intelligent study.

Abstract from Camp's "Notes on Track."

Probably the best general discussion of the subject of creeping rails is that given by W. M. Camp, M. Am. Soc. C. E., in his "Notes on Track," and the writer has taken the liberty of extracting from it a few notes on the general principles. These are given with the object of presenting concisely the best known data on the subject, so that the results here obtained may be better understood.

There are two longitudinal movements in rails:

1.—A molecular movement of expansion and contraction, and

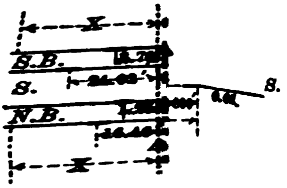
2.—A progressive shifting of the rails bodily, known as creeping.

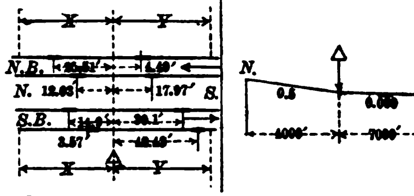
It is now generally conceded that the principal cause of creeping is the wave motion in the rails set up by moving trains.

If each rail, under this wave motion, is not made to hold fast to the ties and the ground, it will remain shoved ahead, by a very small amount, by each passage of a train.

Temperature taken in sun.
"Creep" measured from center line.

LOCATION OF JOI...	...DE	PLEASANTVILLE	
		LOCATION OF JOINTS	GRADE





S.B.TRACK

W. Rail

		X	Y
Jan. 14	29°	[illegible]	30.00
Feb. 11	30°	[illegible]	"
Mar. 11	50°	[illegible]	"
Apr. 7	61°	[illegible]	"
May 7	73°	[illegible]	"
Nov. 24	46°	[illegible]	"

E. Rail

Jan. 14	29°	
Feb. 11	30°	
Mar. 11	50°	
Apr. 7	61°	
May 7	73°	
Nov. 24	46°	

N.B.TRACK

W. Rail

Jan. 14	29°	
Feb. 11	30°	
Mar. 11	50°	
Apr. 7	61°	
May 7	73°	
Nov. 24	46°	

E. Rail

			Y
Jan. 14	29°	30.[illegible]	30.00
Feb. 11	30°	"	"
Mar. 11	50°	"	"
Apr. 7	61°	29.[illegible]	29.995
May 7	73°	29.[illegible]	29.98
Nov. 24	46°	29.[illegible]	29.995

PLEASANTVILLE

N.B.TRACK

E. Rail

		X
Jan. 15	43°	30.00
Feb. 11	42°	"
Mar. 11	55°	29.99
Apr. 8	55°	"
May 8	90°	29.985
Nov. 10	60°	29.99

W. Rail

Jan. 15	43°	
Feb. 11	42°	
Mar. 11	55°	
Apr. 8	55°	
May 8	90°	
Nov. 10	60°	

S.B.TRACK

E. Rail

Jan. 15	43°	
Feb. 11	42°	
Mar. 11	55°	
Apr. 8	55°	
May 8	90°	
Nov. 10	55°	

W. Rail

Jan. 15	43°	30.00
Feb. 11	42°	"
Mar. 11	55°	"
Apr. 8	55°	29.99
May 8	90°	29.98
Nov. 10	55°	29.99

If it were possible to tighten the splices so as to hold against creeping, they would be too tight to allow the rails to expand easily, and much evil would result.

Three important facts should be noted:

1.—The creeping is most rapid during hot weather;

2.—It is greater on double- than on single- track; and

3.—It moves with the trains.

Rails usually creep most on embankments, especially on those newly made, and little or least on solid, hard ground, not raised above the surrounding level. Track laid on swampy or boggy land creeps worst of all.

The manner in which rails will creep, and the amount, depends on:

1.—The character of the ground or foundation for the track;

2.—The direction in which the train loads are heavier;

3.—The proportion of the weight distributed on the two rails;

4.—The speed of the trains; and

5.—The manner in which the ties are spiked.

What Seems to be Shown by the Observations.

A very brief summary of what seems to be shown by the observations is as follows:

1.—At 32 different points to determine which rail moved the most, the right or the left, the following was found:

At 21 points there was no practical difference.

At 8 points the right rail moved most.

At 3 points the left rail moved most. The right crank leads on all engines.

2.—In 7 cases out of 12 the greatest creeping is shown on descending gradients; on the remaining 5 there is practically no difference.

3.—Decidedly more creeping is shown where the roadbed is carried on embankment over swampy ground, than in other places.

4.—More creeping is generally shown on imperfectly maintained track, than where it is kept in first-class condition.

5.—As far as the observations went, it was shown that there was less movement than was expected from the reports of the repairmen, although, in some cases, the points were not at the exact locations of the worst reported creeping.

One of the most interesting points of the series is that at Bethayres, on the New York Branch. At the time the points were located new rails had just been laid, in cold weather, and it had been impossible to space the ties so as to spike all the joints to them. The result was a considerable amount of motion. Between March 17th and April 2d, the west-bound track was fixed, the ties respaced and all the spikes driven in the joints. In spite of this, the movement continued, and was probably due to the disturbance of the roadbed. The Philadelphia, Newtown and New York Railroad crosses this branch a short distance east of this point with a grade crossing, and when the east-bound track was fixed up, about May 2d, the rails were disturbed between the point of observation and the crossing, but the motion continued afterward. The excessive motion is probably due to the fact that at this point the track is not as rigid, longitudinally, as at other points, on account of the crossing frogs at the Newtown crossing and, also, chiefly on account of the swampy ground under the embankment.

The next most serious movement seems to be at Pleasantville, on the Atlantic City Railroad, over the salt marsh, where the movement has been continuous and regular on a nearly level line. The interval of time between the last two observations should be noted.

These two points seem to bear out the principle that creeping is most to be feared when the character of the foundation permits an amplification of the wave motion. The speed of all trains at both of these points is high.

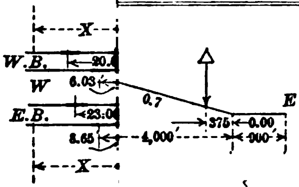
There are a number of facts shown in the tables and diagrams which are very hard to explain, but it is hoped that they may throw some light on points where other records are wanting.

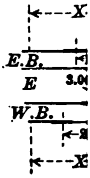
It is to be regretted that more observations were not made on curves, in order to ascertain the effect of the unequal distribution on the two rails caused by heavy, slow-moving freight trains passing around a curve having the proper superelevation for the higher speed of passenger trains.

PLATE XXVII.
PAPERS, AM. SOC. C. E.
MAY, 1904.
WAGNER ON
CREEPING OF RAILS.

R. RY. 1903.

LOCATION	GRADE	LOCATIC





W.B.TRACK

					Y
N. Rail	Jan. 20	32°		30.	30.09
	Feb. 3	49°			"
	Feb. 19	15°			"
	Mar. 4	59°		29.	"
	Mar. 17	61°		30.	"
	Apr. 2	68°		29.	"
	Apr. 16	49°			30.01
	May 2	75°	⊗		"
	May 13	90°			29.995
	May 29	90°			30.00
S. Rail	Jan. 20	32°			
	Feb. 3	49°			
	Feb. 19	15°			
	Mar. 4	59°			
	Mar. 17	61°			
	Apr. 2	68°			
	Apr. 16	49°			
	May 2	75°	⊗		
	May 13	90°			
	May 29	90°			

E.B TRACK

N. Rail	Jan. 20	32°			
	Feb. 3	49°			
	Feb. 19	15°			
	Mar. 4	59°			
	Mar. 17	61°			
	Apr. 2	68°			
	Apr. 16	49°			
	May 2	75°	⊗		
	May 13	90°			
	May 20	90°			
S. Rail	Jan. 20	32°		30.0	30.00
	Feb. 3	49°		30.0	"
	Feb. 19	15°		30.0	"
	Mar. 4	59°		"	"
	Mar. 17	61°		"	"
	Apr. 2	68°		"	"
	Apr. 16	49°		30.0	"
	May 2	75°	⊗	30.0	"
	May 13	90°		"	"
	May 29	90°		"	"

E.B.TRACK

S. Rail	Jan. 20	
	Feb. 3	ed & ballast in.
	Feb. 19	h tracks, but not between them,
	Mar. 4	
	Mar. 17	
	Apr. 2	
	Apr. 16	
	Apr. 28	
	May 12	
	May 29	
N. Rail	Jan. 20	
	Feb. 3	
	Feb. 19	
	Mar. 4	
	Mar. 17	
	Apr. 2	
	Apr. 16	
	Apr. 28	
	May 12	
	May 29	

W.B.TRACK

S. Rail	Jan. 20	
	Feb. 3	
	Feb. 19	
	Mar. 4	
	Mar. 17	
	Apr. 2	
	Apr. 16	
	Apr. 28	
	May 12	
	May 29	
N. Rail	Jan. 20	
	Feb. 3	
	Feb. 19	
	Mar. 4	
	Mar. 17	
	Apr. 2	
	Apr. 16	
	Apr. 28	
	May 12	
	May 29	

shown on this plate.

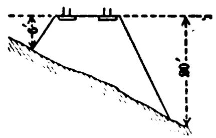
TABLE No. 1.—CREEPING RAILS. ATLANTIC CITY R. R. 1903.

To Accompany Plate XXVI.

Location.	Alignment.	Bearing.	Rails.	Ballast.	Joints.	Cut or fill.	Traffic.	Remarks.
CLEMENTON: Between Station and Garden Lake. 90 ft. north of tel. pole 368.	Tangent.	N. 23° 45' W.	S. B. 90-lb. N. B. 90-lb.	Stone. Stone.	All joints spiked on ties.	Embankment 15 ft. high.	N. B. 27 Passenger, 4 Freight. S. B. 28 Passenger, 5 Freight. Daily.	Subgrade—gravel and sand. Alignment and surface good.
ALBION: Between station and 14 M. P. At tel. pole 458.	Tangent.	N. 37° 45' W.	S. B. 90-lb. N. B. 90-lb.	Stone. Stone.	All joints spiked on ties.	Embankment 12 ft. high.	N. B. 27 Passenger, 4 Freight. S. B. 28 Passenger, 5 Freight. Daily.	Subgrade—gravel and sand. Alignment and surface good.
FARMINGTON: 14 ft. north of north end of station platform.	Tangent.	N. 23° W.	N. B. 80-lb. S. B. 90-lb.	Cinders. Stone.	N. B., Spiked on ties. Standard splices. S. B., Spiked on ties. Bonzano splices.	Slight cut.	N. B. 17 Passenger, 2 Freight. S. B. 17 Passenger, 2 Freight. Daily.	Subgrade—gravel. Alignment and surface good. 45-ft. Rails on S. B. track.
PLEASANTVILLE: 86 ft. south of 51 M. P. on meadows.	Tangent.	N. 57° W.	N. B. 80-lb. S. B. 90-lb.	Cinders. Stone.	Same as above.	Embankment 8 ft. high.	Same as above.	Subgrade—gravel and rocks on salt marsh. Alignment and surface good. 45-ft. Rails on S. B. track.

TABLE No. 2.—CREEPING RAILS. NEW YORK DIVISION, NEW YORK BRANCH, P. & R. RY., 1903.

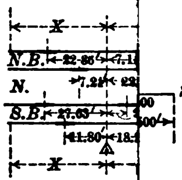
To accompany Plate XXVII.

Location.	Alignment.	Bearing.	Rails.	Ballast.	Joints.	Cut or fill.	Traffic.	Remarks.
BETHAYRES: West end of bridge over Paul Brook.	Tangent.	N. 79° 30′ E.	E. B., 90-lb. W. B., 90-lb.	Stone. Stone.	Spikes not in joints of E. B. track. W. B. track spiked at joints.	Embankment 15 ft. high.	E. B., 41 passenger, 19 freight. W. B., 40 passenger, 20 freight. Daily.	* W. B. track, ties respaced and spiked between Mar. 17 and Apr. 2 at Bethayres. † E. B. track, do. do. Apr. 16. Subgrade — earth fill on marsh. Alignment and surface good. Decided evidence of creeping on E. B. track. Will be spiked as soon as ties can be respaced.
PHILMONT: At 17 M. P.	Tangent.	N. 80° E.	E. B., 90-lb. W. B., 90-lb.	Stone. Stone.	All joints spiked on ties.	Cut 10 ft.	E. B., 41 passenger, 19 freight. W. B., 40 passenger, 20 freight. Daily.	Subgrade—stony soil. Alignment and surface good.
NESHAMINY FALLS: 200 ft. east of road crossing.	Tangent.	N. 78° E.	E. B., 90-lb. W. B., 90-lb.	Stone. Stone.	All joints spiked on ties.		E. B., 41 passenger, 19 freight. W. B., 40 passenger, 20 freight. Daily.	Subgrade—earth fill. Alignment and surface good. Creeping noticed in W. B. track.
HOPEWELL: 84 ft. west of west end of station platform.	Tangent.	N. 64° 30′ E.	E. B., 90-lb. W. B., 90-lb.	Stone. Stone.	W. B. track joints spiked. Large number of unspiked joints in E. B. track.	Cut 10 ft.	E. B., 25 passenger, 18 freight. W. B., 24 passenger, 20 freight. Daily.	Subgrade—earth and soft. Alignment and surface good. No creeping noticed.

Temperature taken in sun. "Creep" measured from center line.

QUA

LOCATION OF JOINTS



N.B. TRACK

E. Rail

		X	Y
Jan. 19	16°	30.00′	30.00′
Feb. 2	45°	30.00′	30.00′
Feb. 18	15°	"	29.998′
Mar. 3	53°	"	30.00′
Mar. 17	49°	"	29.995′
Apr. 1	70°	"	30.00′
Apr. 17	68°	"	29.995′
Apr. 28	75°	"	30.00′
May 12	86°	30.00′	29.995′

W. Rail

Jan. 19	16°		
Feb. 2	45°		
Feb. 18	15°		
Mar. 3	53		
Mar. 17	49°		
Apr. 1	70°		
Apr. 17	68		
Apr. 28	75°		
May 12	86°		

S.B. TRACK

E. Rail

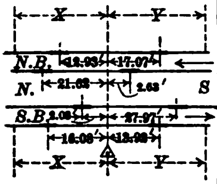
Jan. 19	16°		
Feb. 2	45°		
Feb. 18	15		
Mar. 3	53		
Mar. 17	49°		
Apr. 1	70°		
Apr. 17	68°		
Apr. 28	75°		
May 12	86°		

W. Rail

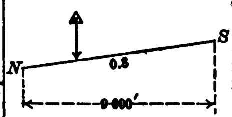
		X	Y
Jan. 19	16°	30.00′	30.00′
Feb. 2	45°	"	29.99′
Feb. 18	15°	"	29.995′
Mar. 3	53°	19.995′	29.98′
Mar. 17	49°	19.99′	"
Apr. 1	70°	19.975′	29.97′
Apr. 17	68°	19.98′	"
Apr. 28	75°	19.96′	"
May 12	86°	"	"

ORELAND

LOCATION OF JOINTS



GRADE



N.B. TRACK

E. Rail

		X	Y
Jan. 19	36°	30.00′	30.00′
Feb. 2	52°	"	29.99′
Feb. 18	18°	30.003′	30.015′
Mar. 3	53°	30.00′	29.99′
Mar. 17	63°	"	29.985′
Apr. 1	76°	30.01′	"
Apr. 17	67°	30.005′	29.99′
Apr. 28	93°	"	29.985′
May 12	97°	30.00′	29.98′

W. Rail

Jan. 19	40°		
Feb. 2	51°		
Feb. 18	21°		
Mar. 3	56°		
Mar. 17	63°		
Apr. 1	76°		
Apr. 17	67°		
Apr. 28	93°		
May 12	97°		

S.B. TRACK

E. Rail

Jan. 19	40°		
Feb. 2	51°		
Feb. 18	21°		
Mar. 3	56°		
Mar. 17	63		
Apr. 1	76°		
Apr. 17	67°		
Apr. 28	93°		
May 12	97°		

W. Rail

		X	Y
Jan. 19	40°	30.00′	30.00′
Feb. 2	51°	"	"
Feb. 18	21°	30.018′	30.01′
Mar. 3	56°	30.00′	29.988′
Mar. 17	63°	29.99′	29.995′
Apr. 1	76°	29.98′	"
Apr. 17	67°	29.99′	29.99′
Apr. 28	93°	29.98′	29.985′
May 12	97°	"	29.99′

TABLE No. 3.—CREEPING RAILS. NEW YORK DIVISION, BETHLEHEM BRANCH, P. & R. RY. 1903.

To accompany Plate XXVIII.

Location.	Alignment.	Bearing.	Rails.	Ballast.	Joints.	Cut or fill.	Traffic.	Remarks.
QUAKERTOWN: 80 ft. north of Hall signal, 825 ft. north of yard switches.	Tangent.	S. 26° E.	S. B., 90-lb. N. B., 80-lb.	Slag. Slag.	West rail of S. B. track not spiked on account of creeping. All other joints spiked to ties. Standard joints.	No cut or fill.	N. B., 12 passenger, 11 freight. S. B., 12 passenger, 11 freight. Daily.	Alignment and surface fair. Shortage of ballast between ties Subgrade—earth. Foreman reports west rail of S. B. track creeps to south. Last summer it moved 12 in. ties at joints show creeping.
NORTH WALES: 780 ft. south of 22 M. P. south of station.	0° 30 curve. 4 223 ft. long.	S. 17° 30′ E. Tangent to curve.	S. B., 80-lb. N. B., 80-lb.	Slag. Slag.	All joints spiked on ties.	Rock cut 20 ft. deep.	N. B., 26 passenger, 12 freight. S. B., 26 passenger, 12 freight. Daily.	Alignment and surface fair. Shortage of ballast between ties. Subgrade—rock. No signs of creeping.
GWYNEDD: 800 ft. south of stone arch bridge.	Tangent.	N. 26° 15′ W.	N. B., 80-lb. S. B., 80-lb.	Slag. Slag.	All joints spiked on ties.	Slight cut.	N. B., 26 passenger, 11 freight. S. B., 26 passenger, 12 freight. Daily.	Alignment and surface fair. Shortage of ballast between ties. No signs of creeping.
ORELAND: 875 ft. north of road crossing north of station.	Tangent.	N. 56° 30′ W.	N. B., 80-lb. S. B., 80-lb.	Slag. Slag.	Some joints spiked to ties, others are not.	Cut 5 ft. deep.	N. B., 26 passenger, 12 freight. S. B., 26 passenger, 14 freight. Daily.	Alignment good. Surface fair. Shortage of ballast between ties. East rail, N. B. track, creeps north, and is shown by ties. Rails on N. B. track close together at station and open out as you go north.

TABLE No. [illegible] [illegible] New York Division, [illegible] P. R. R. [illegible]

[illegible] Plate [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	N [illegible] W	N [illegible]	Slag Slag	All joints spiked on ties	Slight cut	N. B. [illegible] passenger, 11 freight. W. B. [illegible] passenger, 10 freight. Daily.	Alignment and surface fair. Shortage of ballast between ties. No signs of creeping.
[illegible]	[illegible]	[illegible]	N. B. [illegible]	Slag.	Some joints spiked to ties, others are [illegible]	Cut 5 ft. deep.	N. B., 30 passenger, 12 freight, [illegible]	Alignment good. Surface fair. Shortage of ballast between ties. [illegible]

TABLE No. 4.—CREEPING RAILS. READING DIVISION, FRACKVILLE BRANCH, P. & R. RY. 1903.

To accompany Plate XXIX.

Location.	Alignment.	Bearing.	Rails.	Ballast.	Joints.	Cut or fill.	Traffic.	Remarks.
HEAD OF GRADE: At telegraph pole 285.	Tangent.	N. 80° W.	S. B., 90-lb. N. B., 90-lb.	Cinders. Cinders.	Both rails of N. B. track spiked. Occasional joints on S. B. track are spiked, say, one-third (?). Standard splices.	Cut on side of mountain.	N. B., 7 passenger, 65 freight. S. B., 7 passenger, 65 freight.	Alignment and surface fair for conditions. Foreman reports difficulty with creeping on S. B. track. He cut five places last year. Rails last but 18 months. Evidence of movement at joint ties.
BROAD MOUNTAIN: 860 ft. north of the station.	1° 30′ curve.	N 5° W. Tangent to Curve.	S. B., 90-lb. N. B., 90-lb.	Cinders. Cinders.	Both rails of N. B. track spiked. On S. B. track a number not spiked. Standard splices.	Cut on side of mountain.	Same as above.	See above note.

SHAMOKIN DIVISION, MAHANOY AND SHAMOKIN R. R., P. & R. RY. 1903.

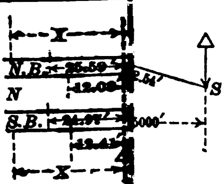
Location.	Alignment.	Bearing.	Rails.	Ballast.	Joints.	Cut or fill.	Traffic.	Remarks.
LOCUST DALE JUNCTION: 68 ft. north of switch in S. B. track.	Tangent.	S. 80° W.	S. B., 90-lb. N. B., 80-lb.	Cinders, Cinders.	All joints spiked on ties.	No cut or fill.	S. B., 11 passenger, 14 freight, 41 light engines. N. B., 11 passenger, 30 freight. Daily.	Surface and alignment good. Decided evidence of creeping on S. B. track, where foreman reports trouble, especially in summer.
LOCUST SUMMIT: South of bridge, below the station.	Tangent.	N. 88° E.	S. B., 90-lb. N. B., 80-lb.	Cinders. Cinders.	All joints spiked on ties.	Cut 15 ft. deep.	Same as above.	Same note as above.

PLATE XXIX.
PAPERS, AM. SOC. C. E.
MAY, 1904.
WAGNER ON
CREEPING OF RAILS.

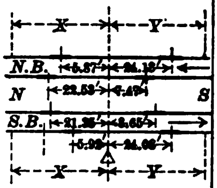
CREEPING [illegible] AHANOY AND SHAMOKIN R. R.- P. & R. R. R.

HEAD OF [illegible] — LOCUST SUMMIT: SHAMOKIN DIV.

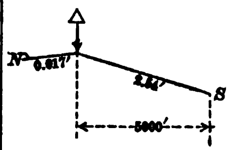
LOCATION OF JO[illegible] ... DE.



LOCATION OF JOINTS.



GRADE.



N.B. TRACK

			Y
E. Rail	Feb. 16	36°	30.00
	Mar. 2	44°	29.90
	Mar. 16	30°	"
	Mar. 31	58°	———
	Apr. 13	49°	29.90
	Apr. 27	30°	"
	May 11	34°	"
	Jun. 2	86°	"
	Sep. 26	61°	———

			X	Y
E. Rail	Feb. 16	35°	30.00	30.00
	Mar. 2	61°	"	29.985
	Mar. 16	43°	"	30.00
	Mar. 30	35°	———	———
	Apr. 13	52°	———	30.00
	Apr. 27	95°	———	"
	May 11	96°	30.00	"
	Jun. 2	93°	"	"
	Sep. 26		Stake lost	

W. Rail	Feb. 16	36°
	Mar. 2	44°
	Mar. 16	30°
	Mar. 31	58°
	Apr. 13	49°
	Apr. 27	30°
	May 11	34°
	Jun. 2	86°
	Sep. 26	61°

W. Rail	Feb. 16	35°	
	Mar. 2	61°	
	Mar. 16	43°	
	Mar. 30	35°	
	Apr. 13	52°	
	Apr. 27	95°	
	May 11	96°	
	Jun. 2	93°	
	Sep.		Stake lost

S.B. TRACK

E. Rail	Feb. 16	36°
	Mar. 2	44°
	Mar. 16	30°
	Mar. 31	58°
	Apr. 13	49°
	Apr. 27	30°
	May 11	34°
	Jun. 2	86°
	Sep. 26	61°

E. Rail	Feb. 16	35°	
	Mar. 2	61°	
	Mar. 16	43°	
	Mar. 30	35°	
	Apr. 13	52°	
	Apr. 27	95°	
	May 11	96°	
	Jun. 2	93°	
	Sep.		Stake lost

				Y
W. Rail	Feb. 16	36°		30.00
	Mar. 2	44°	Wo[illegible]	"
	Mar. 16	30°		"
	Mar. 31	58°		———
	Apr. 13	49°		30.00
	Apr. 27	30°		"
	May 11	34°		29.90
	Jun. 2	86°		"
	Sep. 26	61°		30.00

			X	Y
W. Rail	Feb. 16	35°	30.00	30.00
	Mar. 2	61°	"	29.985
	Mar. 16	43°	"	30.00
	Mar. 30	35°	———	———
	Apr. 13	52°	———	30.00
	Apr. 27	95°	———	"
	May 11	96°	30.00	"
	Jun. 2	93°	"	"
	Sep.		Stake lost	

Vol. XXX. MAY, 1904. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

LATERAL EARTH PRESSURES AND RELATED PHENOMENA.

Discussion.*

By Messrs. M. F. Bonzano, V. H. Hewes and H. F. Dunham.

M. F. Bonzano, M. Am. Soc. C. E. (by letter).—There has been too little investigation of this important subject, and it is gratifying to have Mr. Goodrich's paper. The writer has for years looked forward to having an opportunity to make some investigation with a view of securing some reliable data upon this subject. Mr. Bonzano.

The writer has noticed that the shrinkage of dumped material is in the direction in which it flows when dumped, and that the principal lines of pressure are substantially in the same direction, and, as a result, has introduced into specifications for graduation the following:

"In depositing filling material against abutments, piers, or walls, it must always be dumped away from masonry; never toward it. As the shrinkage of material is always in the direction in which it flows when dumped, especial pains must always be taken to make the shrinkage-thrust away from masonry structures. When filled material is tamped or rammed after dumping, the ramming should be done by vertical blows."

The foregoing is quoted from printed specifications prepared by the writer, and is believed to be original and not to be found elsewhere.

* This discussion (of the paper by E. P. Goodrich, Jun. Am. Soc. C. E., printed in *Proceedings* for March, 1904), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to June 25th, 1904, will be published subsequently.

Mr. Bonzano. The specifications resulted from the writer's observations of the results of different ways of dumping and handling material, and such results are noted briefly as follows:

1.—A first-class masonry structure is usually ruined by being dumped against by a tail dump, the structure being forced out of plumb.

2.—A masonry structure, of inferior and light design and of poor material and workmanship, will give astonishingly good results if the filling is deposited back of it so as to flow away from it when dumped.

3.—The greater the shrinkage of the filling material and the higher the dump, the greater the force or pressure due to flow and shrinkage.

4.—The flow and shrinkage pressures are greatest in the longest layers of dumped material.

5.—The flow and shrinkage forces are in the direction of the flow of the material when dumped.

The results just described may easily be confirmed by observation. If an embankment 50 ft. high is made by dumping from both sides of a trestle—no matter whether the shrinkage of the material is small or great—it can be noticed that, after the embankment is completed, vertical cracks appear near the center line, and that frequently they are quite wide and extend downward a great many feet. If all the material filled back of an abutment is dumped so as to flow away from it, after the first soaking rain, a space can be found between the filling and the abutment that varies in width approximately in proportion to the height of the dump and the coefficient of shrinkage of the material.

The writer doubts the value of the data secured by Mr. Goodrich, and feels confident that, for practical use, the data must be obtained by considering primarily the direction of flow when dumped, together with determining the coefficients of shrinkage. The writer could cite many interesting cases from which the foregoing conclusions were derived.

Mr. Hewes. V. H. Hewes, M. Am. Soc. C. E.—The author's description of the method used in obtaining the pressure has given the speaker an idea which it might be well to mention, so that someone may take it up, in future experiments, and elaborate it.

Taking into consideration the principle that carbon changes in electrical conductivity when placed under varying pressure, raises the point that, would it not be possible to place a carbon cylinder, or carbon in any shape, of a certain length, back of the retaining wall, and place the piece of carbon in circuit with a battery and galvanometer, and in that way get the deflections as the pressure varies on the piece of carbon? The conductivity being the reciprocal of its resistance, it would be more accurate and convenient to use a "Wheat-

stone bridge" to measure the variations of resistance due to changes of pressure. The carbon might be covered with a material which would prevent it from taking up moisture, which would cause a change in its resistance. Also, the piece of carbon might be placed in the mass of the material itself, and, in that way, the resistances could be obtained as the pressure on the carbon increased. The ends of the carbon could be exposed to the mass of the material, while the sides could be protected by a box, from which the ends would protrude, in that way causing the pressure to come on the ends of the carbon. The axis of the carbon could be placed in any direction in which the pressure was to be observed. Mr. Hewes.

It might also be easy, in such cases, to have two or three sets of carbons placed in the mass of the material to be tested, and, by simply having a small switchboard, the experimenter could measure first one circuit and then another. The carbon might remain in for any length of time, and follow the changes from month to month.

It might be stated that, in using the block of carbon, all arching effects might be eliminated.

H. F. Dunham, M. Am. Soc. C. E.—In describing curves of the variety under discussion, a positive check, or comparison with a pressure exactly known, would be valuable. If water were used as a material for "the fill," either in a cylinder or against planks, the precise pressure could be determined. The deflection could be compared with that observed for other material, or a curve for water under different heads could be compared with one for silt, quicksand or wet clays. It would be interesting to know whether this has been done. Mr. Dunham.

Vol. XXX. MAY, 1904. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A PHENOMENAL LAND SLIDE.

Discussion.*

By Messrs. D. D. Clarke, George L. Dillman and Arthur L. Adams.

Mr. Clarke. D. D. Clarke, M. Am. Soc. C. E. (by letter).—The paper gives the history of the slide, down to the first of January, 1904, showing in detail the surveys upon which claims for the success of the reclamation work have been based. The writer believes that any claims he may have made are fully warranted by the results achieved, as shown by the charts submitted with the paper. That the result of a later survey, completed during the early part of March, 1904, portends an unexpected change in conditions formerly existing, may probably be taken as another proof of the "phenomenal" character of the movement

As has been indicated, a resurvey of the range lines crossing the slide shows a slight change at a number of the points observed, a larger proportion of the points giving readings greater than for any former survey for two years. About 60% of the points observed gave readings ranging from 0.01 to 0.02 ft. in excess of former surveys. There were about half a dozen points which gave readings in excess of 0.02 ft., and only one as much as 0.05 ft., the average of points shown on the diagram, Plate IX (east and west lines X′, A″ + 10 and D″), being 0.13 in. for the months of January and February, or 0.065 in. per month. This is indeed a small variation, and is significant

* This discussion (of the paper by D. D. Clarke, M. Am. Soc. C. E., printed in *Proceedings* for March, 1904), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to June 25th, 1904, will be published subsequently.

only as an indication of the possibilities of the situation, which will require additional time to develop fully. Mr. Clarke.

This unlooked-for change is unquestionably due to the unusual rainfall of the last four months, November, 1903, to February, 1904, inclusive. That this rainfall has been excessive is shown by the following figures compiled from the reports of the United States Weather Bureau in Portland.

The total rainfall for the months of November and December, 1903, and January and February, 1904, was 30.15 ins. This amount is 14.7% more than the average for these months for 34 years, and 27% more than the average for the same period during the past 21 years (1883 to 1904). It should be said, however, that the average for 13 years (1870 to 1883) was 30.4 ins., or slightly in excess of that for the present season.

The average rainfall during the months the Weather Bureau calls the "Wet Season"—September 1st to May 31st—is 42.39 ins., while the yearly average is 45.70 ins. Comparing the present season with the foregoing, the following may be noted.

Total precipitation	November, 1903	10.71 ins ,	
"	"	December, 1903	3.14 "	
"	"	January, 1904	5.22 "	
"	"	February, 1904	11.08 "	
				30.15 ins.,
"	"	March 1st to 28th, 1904		8.64 "
Total				38.79 ins.,

the latter amount being about 85% of the yearly average.

The severity of these storms has also been shown by the volume of the drainage from the tunnels, which, upon a number of occasions, has been at the rate of more than 100 000 galls. per day. This shows in a striking manner the efficiency of the present tunnels. If this volume of water were not allowed to escape so freely, there would be trouble indeed, and the original "saw-tooth" character of the movement chart would soon reappear.

Considering the volume of rainfall and drainage, it is probable that the next survey will also show unfavorable results, for it will require some time for the ground to dry out after the rain has ceased.

That the movement is likely to continue for an indefinite period (if, indeed, it can be said that a general movement has already commenced), the writer does not consider at all probable. In order that the grounds for this confidence may appear, attention is called to Table No. 10, a comparative statement of the rate of the movement between January, 1895, and March, 1904.

Mr. Clarke.

TABLE No. 10.

Dates.	Length of period, in months.	Movement.		Remarks.
		Total, in inches.	Inches per month.	
January, 1895, to June, 1900.....	55	46.76	0.85	Reservoir linings wrecked during this period.
June, 1900, to November, 1901...	17	1.68	0.10	Tunnel construction in progress.
November, 1901, to March, 1904..	28	0.47	0.02	Period since completion of tunnels.

The last-named amount includes the movement just observed, which amounts to 0.13 in. for the months of January and February, 1904, and, with that amount included, the average recorded movement has been less than one-fortieth of the average before the tunnels were completed.

It may be noted that, by the last survey, there were very few points opposite Reservoir No. 3 which showed an increased reading, the greater number being along the axis of the slide opposite the north end of Reservoir No. 4.

The effects of the present severe storms are simply regarded as so many indications that the tunnels already constructed are not sufficient to drain thoroughly the entire mass of the sliding ground and its underlying bed-rock. The Water Board recognizes this condition of affairs, and, even now, has under consideration the construction of additional bed-rock drains, as branches of the main tunnel; and also a system of sub surface tile drains to cover certain portions of the surface, provided later surveys afford conclusive proof of the necessity for this additional drainage work.

The result of the changes, already noted, will be to delay somewhat the work of reservoir repairs, but there is no doubt felt of the ultimate success of the reclamation work and the final restoration of the reservoirs.

* * * * * * * *

During May, 1899, while the writer was engaged upon the investigation of the slide at the Portland reservoirs, there appeared in the city papers brief accounts of an immense land slide which had just occurred near Cape Meares, about 70 miles west from Portland.

The first descriptions of the slide, its size and the rapidity of its movement (width ½ mile, length 4 miles, and movement 2 ins. per hour) were sufficiently startling to awaken a desire to examine the ground and see if the conditions actually existing there were in any way com-

parable with those which had been studied so long at Portland. A few weeks later, therefore, the writer undertook the journey, partly by rail and boat, but chiefly by stage or mudwagon, crossing the Coast Range, and occupying 36 hours or more, before reaching the slide. The time spent in the vicinity was three and a half days, and the greater part of two days was occupied in mapping the slide and noting its characteristics and progress. From the notes then taken the map, Fig. 7, and description of the slide have been prepared. Mr. Clarke.

The slide is in a shallow depression lying immediately north of the range of hills of which Cape Meares is the western extremity, and is about 5 miles south of the entrance to Tillamook Bay, Oregon. The upper or eastern portion of the slide is covered with a dense forest, and it is not easy to determine the exact limits of the moving ground, but enough is known to warrant the statement that the length of the slide from the ocean beach to its eastern extremity is a little less than ½ mile, and the average width about 500 ft. The area of the moving ground is approximately 30 acres.

The larger part of the moving ground is covered with a dense forest of fir, spruce and smaller growths, and little can be seen which indicates in any way the probable depth of the movement. The movement has been sufficient to cause many trees to fall around the margin of the slide, and many more will soon follow.

The head of the slide reaches an elevation of about 300 ft. above the ocean beach in a distance of about ½ mile.

From present appearances, and from information derived from those familiar with the ground as it was before the slide occurred, it can be said that the slide had its origin in a small tract of swampy ground, perhaps 200 x 300 ft. in extent, through which ran two small streams of water, each perhaps 12 ins. wide and 1 or 2 ins. deep. One of these small streams finds its way to the beach along the base of the Cape Meares ridge, the southern limit of the slide being for the most part along or within a few feet of the bed of this stream.

The second small stream crosses the upper end of the slide to near its northern border, and thence finds its way to the beach, its course being almost, if not altogether, within the limits of the moving ground.

On the south, the line of the movement is defined very clearly, as it follows, for the most part, the bed of the creek until within about 400 ft. of the beach, where it leaves the channel of the stream and cuts through higher ground on a more direct course. Along the northern border, the ground is broken more irregularly; piled in ridges in places, with crevices between; but none of the latter was of any considerable depth.

At the head of the slide the horizontal movement has been sufficient to remove all timber and surface earth from a section of the hill-

Mr. Clarke. side about 400 ft. long, from north to south, and 50 to 70 ft. wide, measured along the slope of the bank. The slope of the clay bank, where exposed by the slide, is from 25° to 40°, and the vertical movement at that point amounts to about 30 ft. No chasm was to be seen, indicating a deep movement at that point; the ground had simply settled away from the adjoining bank, and all crevices had been filled with the surface earth loosened by the slide. At one point a rocky ledge had been exposed, and all around the upper margin of the slide the upturned trees indicated but a slight depth of surface earth.

While the upper or eastern portion of the slide is hidden from view by a dense forest, the lower part has been cleared of timber to a great extent, and is partly under cultivation; but, at the beach, existing conditions bear the strongest testimony to the force and magnitude of the movement. The height of the bank above extreme high tide varies from zero at the center of the slide to 10 ft. above at the north side, and 20 to 25 ft. at the southern edge of the movement. Excepting at either margin of the movement, the portion of the bank above high tide shows no appearance of having been disturbed, although it has been moved 200 ft. or more from its original position, but the beach in front, for another 200 ft. or more, has been thrown up into ridges or folds by the immense pressure from the slide.

This movement has extended out to low-water line or beyond, and a nearly vertical bank, 10 ft. in height, formed of clay and sand in large masses, presents a bold front to the action of the waves, which slowly wear it away.

As far as known, the movement began on or about May 10th, 1899. By measurement, it was found that the total movement from May 10th to June 10th was 228 ft., or an average of 7.36 ft. per day.

From June 10th to June 12th it was at the rate of 4.01 ft. per day.

From June 12th to June 13th it was at the rate of 3.26 ft. per day.

From the foregoing, it appears that a falling off in the rate of the movement had already commenced at the time the examination was in progress. Considering the not excessive slope of the hillside, it was rather surprising to find that the movement had continued for such a length of time, and it did not appear unreasonable to suppose that it would soon cease altogether. This, however, was merely conjecture, for the movement no doubt depended upon the quantity of water which found its way under the slide, near its head, and what its volume might be no one could tell.

Some months after the writer's return from this examination he was informed that an entire cessation of the movement had taken place which must have occurred very soon after the last measurement was taken, June 13th, 1899.

The writer has no report regarding the condition of this slide later than June 13th, 1900. There had then been no resumption of the

Mr. Clarke.

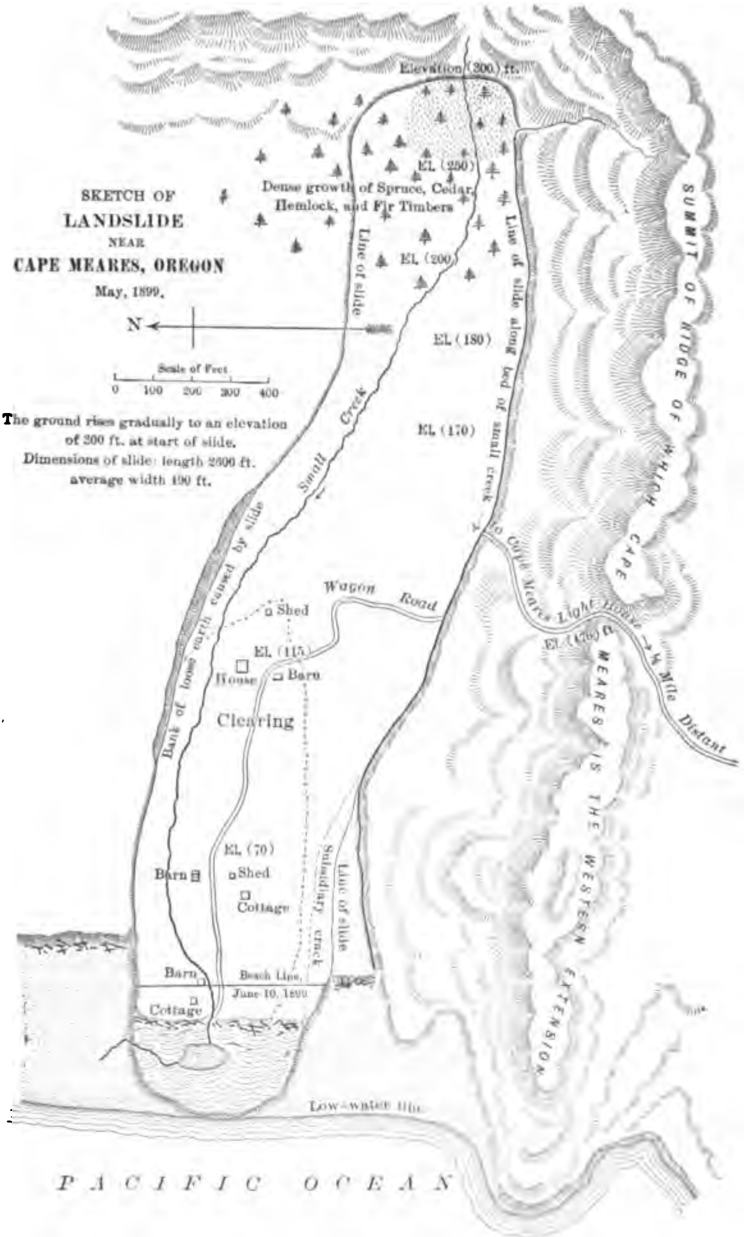


FIG 7.

Mr. Clarke. movement during the winter which intervened since the measurements were taken. It was also reported that the front of the slide had been worn away by the action of the waves as far back as the dotted line in Fig. 7.

Mr. Dillman. GEORGE L. DILLMAN, M. AM. SOC. C. E. (by letter).—The writer's acquaintance with this ground began in 1891, when he had charge of the construction of the cable road (shown in Plates IV, V, VI and IX)* for the contractors. In 1898 he was employed by the City of Portland to study and make a preliminary report on the sliding land case, then in litigation. In 1899 he was one of the witnesses for the city at the trial mentioned.

Months before the completion of the cable road, it was known that the Cable Company would default in payments. The writer's business was to save as much as possible from the wreck, which may account for his neglect to appreciate the importance of several facts developed during construction. At any rate, their significance was not appreciated until later. These facts, as memory serves, include the following:

1.—From Boring No. 3 to Shaft No. 9 (see Plate IX) the road was in a cut. Shortly after the grading was done, cracks in the slopes indicated motion, thought at the time to be local. These were obliterated by sloughing, after the rails were laid, at one time covering the finished track several feet deep.

2.—The track mentioned had a tendency to buckle, and both the slot and the running rails were cut to relieve the pressure. This part, however, was on a heavy grade (about 35%). The plan called for very light construction, so that insufficient anchorage might have been considered the cause of this trouble.

3.—The level track northward from Shaft No. 9 got badly out of line, the derangement not being confined to fills, but extending into cuts. The derangement on fills was thought to be from shrinkage; in cuts it was thought to be from the same local movement noted in Fact 1.

4.—In re-aligning the track northward from Shaft No. 9, there was considerable friction between the foremen and the engineers, the former complaining that the engineers could never run their lines twice alike, the latter that their stakes were disturbed.

5.—Expert timber men made failures in felling trees in the direction desired.

6.—There was a swampy hillside north of the timber-trestle bridge across what was later Reservoir No. 4.

7.—At one time the bents of this timber trestle were very much out of plumb, and their tops were jacked back, down hill.

* *Proceedings*, Am. Soc. C. E., for March, 1904.

In the examination of 1898, the first pertinent fact of importance developed was the lack of coincidence of the surface of movement and the depths of excavation, being many feet below Reservoir No. 3 and many feet above Reservoir No. 4. Mr. Dillman.

There was a rupture of the lining of Reservoir No. 4 at about the bottom of the reservoir, which is, however, best accounted for by its construction. The clay back of the facing (concrete and asphalt) was carefully puddled. The water was in the reservoir several days, then quickly drawn off, so that any small seepage through the facing, or backed-up ground-water, would act with its full head on this weakest point. Thus, the reservoir lining contained within itself all that was necessary to its own destruction under the conditions imposed. The rupture near the bottom of Reservoir No. 4, therefore, had no necessary connection with the slide.

The extent and amount of the movement had been ascertained at this time. Colonel Mendell had directed investigations which were exhaustive and conclusive. His conclusions have been verified by the subsequent work of drainage, as shown by the paper.

The investigation of this slide is by far the most complete of which the writer has any knowledge. It seems to make plain that the water does the damage, not so much by its volume or weight as its pressure, and, at the surface of motion, acts like a myriad of jack-screws to lift, and at the same time lubricate it, the same pressure forcing the water into and through otherwise impervious strata.

The writer knows of many slides which have been cured by drainage, and knows of no failures to do so when the remedy was applied properly, and in the right places.

There are several sermons in this slide, one of which is on the fallacy of taking generally accepted facts for verities. Prior to this law suit, everybody seemed to know that the excavation of the reservoirs caused the slide. The Northwest is full of slides. The construction of every railroad develops them. The fact that cutting off the toe of a slope with sliding tendencies often starts a slip was warrant for this general belief. The traces of the slide on the surface were pretty well hidden by undergrowth. There were no buildings. The cable road was abandoned, but this might have been from other reasons than failure to maintain it. Engineers, looking casually at the reservoir failures, granted it. A prominent and capable engineer, well acquainted with slides, refused to investigate it for the city because he did not care to be bullyragged by contending attorneys over a point, to him, so evident. The predecessor to the City Attorney who won the case had made some investigation, and told the writer just prior to the trial that the only ground for the city to stand on was to deny liability first, then get the damages as low as

Mr. Dillman. possible; that there was no use in contending against such obvious facts.

The investigations, under the direction of Colonel Mendell, indicated that there might be some doubt. The City Attorney, following this lead, found evidence of motion prior to the excavation of the reservoirs. Then the cable road operation and difficulties during construction seemed pertinent. Officers of the militia had had their target ranges on this ground, and noticed the derangement of stakes which should have been in line. Men were found who, when boys, had herded cattle on this ground and had lost cattle in the cracks at the head of the slide. All this was made so plain to the jury that they were absent only long enough to frame a verdict for the city. After the trial, everybody knew that this was an ancient slide. It was astonishing to find that so many people had known it all the time.

Mr. Adams. ARTHUR L. ADAMS, M. AM. SOC. C. E. (by letter).—It seems very probable that no land slide has ever received such exhaustive study as has been given to the one described in this paper.

Few slides have been productive of more embarrassing results, and engineers in general will unite in the hope that, as a reward of such long and patient effort as that described, this one has now "become an event of the past."

The recounting of methods by which great difficulties are finally overcome is always of value, and to this the paper is not only no exception, but, on the contrary, it ranks, in the estimation of the writer, among the best of its class in engineering literature.

Land slides are by no means uncommon on the Pacific Coast, from San Francisco north. The mountainous character of the country, the clayey nature of the soil overlying the bedrock, and the heavy seasonal rainfall, are all favorable for their production. Scarcely a winter passes in which railroads are not repeatedly blocked, even on lines which have been in operation for years, and if the rain chances to be unusually abundant, or unusually protracted at any time, the recurrence of such slides becomes correspondingly frequent.

In many localities the slopes, in their natural state, are lying at what is virtually their maximum angle of repose in wet weather, and what may seem to be an insignificant side-hill cutting may be sufficient to destroy the existing equilibrium and start motion. This is also true of many large slides of broken trap rock, along the slopes of which railroad lines, in places, are maintained with the greatest difficulty. Even the wash of banks, incident to unusually high water on the Columbia River, for instance, has been sufficient to set in motion land on which improvements had existed for years without suspicion of instability.

During the building of the Portland reservoirs, the writer was in

charge of the construction of a system of water-works at Astoria, Oregon, where the geological conditions were almost identical with those about Portland, and where slides and land of doubtful stability were so abundant that great caution was called for in locating reservoirs and other permanent structures, and made it necessary to use slip-joints and other special devices in the pipe system where unstable ground could not be avoided. He was therefore a frequent visitor, and a much interested observer of the progress of events, at Portland. Mr. Adams.

The author expresses the hope that some of the engineers engaged by the plaintiff, in the trial of the interesting case of the King Real Estate Company *versus* The City of Portland, will avail themselves of the opportunity for discussion afforded by the publication of his paper. This the writer does more willingly because the ruling of the judge, in the trial of the case, prevented any review, by engineers for the plaintiff, of the expert evidence of the defense, with the result that the very essence of difference in expert opinion was obscured and lost because it was never driven home to the minds of the highly agricultural jury, carefully selected in compliance with law from without the limits of Portland, to try this very technical case. The experts engaged by the plaintiff were called in too late to make any suitable presentation by way of exhibits, an indispensable prerequisite to success, especially before a jury; while the defense, as the result of a year's preparation, combatted with a magnificent line of exhibits, of which the engineer-authors had just reason to be proud. The jury was duly overwhelmed; the engineers engaged by the plaintiff were not permitted to review; with the result, as has been stated, that the essential point of difference in the expert opinion was obscured and lost on the jury, to the satisfaction of the defendant and the grief of the plaintiff.

There was substantially no difference of opinion:

1.—Concerning the existence, character and dimensions of the slide, as it existed at the time of the trial;

2.—That without water there would, of course, have been no movement, whether or not the reservoirs had been built;

3.—That numerous instances of local surface sliding had been observed on the land prior to, as well as during, the reservoir construction;

4.—That there had been trouble, prior to the commencement of work on the reservoirs, in maintaining the surface and alignment of the cable road;

5.—That no deep-seated or general movement of the greater slide had ever been discovered or credibly suspected prior to excavating the reservoirs.

The fundamental question really involved in the expert evidence did not concern these matters at all, but was:

Mr. Adams. Had the great slide been in motion during a period of years prior to excavating the reservoirs? If not, was this excavation the disturbing cause which upset the pre-existing condition of equilibrium and started or renewed the motion?

It will be observed in the statement that whether or not this land had at an ancient time been in motion is not involved in the technical controversy, no matter what bearing it might legally have upon the question of damages; but only the question as to whether it was permanently at rest prior to commencing work on the reservoirs.

There are several important matters, in addition to those mentioned in the paper, which are necessary for a full understanding of the situation. They are as follows:

First.—The high ridge lying immediately east of the two reservoirs and across the front of the slide, and through which the ravine in which the reservoirs were built passes at the narrow outlet closed by the dam of Reservoir No. 4, is a rocky barrier of unquestioned stability. (See Plate IV.)

Second.—The small streams originally flowing during the rainy season in the depressions in which the reservoirs were afterward built were not of an erosive character.

Third.—In excavating the reservoirs, not only were the slopes cut back and increased in pitch far beyond the point of stability for wet clay, but the ravines were much deepened by making the reservoir bottoms much below the prior existing natural elevations. The paper does not give the various depths of this cutting, but they were shown as a part of the defendant's exhibits. On page 173* the author mentions a 41-ft. cutting, but the writer's recollection is that it was generally much less.

Fourth.—The tract, including a large part of the land later found to be in motion, had been subdivided and staked out, as indicated in Plate IV, five years before the cable road was built and six years before the excavation of the reservoirs was started; and it was proven by Mr. Quinn, the engineer who had made the subdivision and who had thereafter resurveyed the tract, closing on the original stakes, that there was a complete absence of any general movement between 1887 and 1893.

The theories and interpretation of evidence on the part of the defense tended toward the demonstration of the existence of the large general slide, as described in the paper, presumably dating in origin far into the past, and which, up to the present, had not come to a condition of repose; in short, that the ground had been moving every year, but without this movement having been discovered previously.

In the opinion of the writer and others associated with him, there

---

* *Proceedings* Am. Soc. C. E. for March, 1904.

were many insurmountable difficulties in the way of the acceptance of this theory; while the hypothesis that the slide, even though of ancient origin, had long ago come to a state of rest against the rocky barrier directly in its path, to be again set in motion by the removal of the supporting earth and broken rock, satisfied, in their judgment, every material point of evidence as to fact, and was fully warranted from a study of the physical conditions. Mr. Adams.

Some of the difficulties in the way of the acceptance of the theory of the defense were:

First.—The failure of the Portland Water Committee and its engineers, during two years of study and investigation prior to commencing work, to discover this movement, although cautioned by intense public opposition to the sites proposed, because of their feared instability.

Second.—It was utterly at variance with the evidence of Mr. Quinn, who had subdivided the tract and resurveyed it years later, as hereinbefore recited.

It was also at variance with much other, less conclusive, but still good indicative, evidence that there had been no movement for a much longer period than that covered by Mr. Quinn's observations, and none at any prior time, as far as known.

To substantiate the claims of continuous movement, it was necessary to attribute the various difficulties with the cable line, during the short period of its operation, from May, 1892, until the following September, to this cause. Therefore, in the trial, great stress was laid upon this by the defense.

If the phenomena observed on this road are accounted for by the existence of local surface slides and the exigencies of operating a new road in this locality, a cable road at that, during the first year of its completion, then the theory of the engineers for the plaintiff is incontrovertible and all material evidence is reconciled. The writer is convinced that, not only can these phenomena be thus accounted for, but that, on the contrary, the theory of a general, deep-seated movement cannot account for them at all.

As to the character of this cable road, as given in evidence: It was built in the rainy season. On Kingston Avenue, in the vicinity where the greatest lateral movement was observed, the track was on a fill, 30 ft. high, built on a hillside so steep that the bank was 20 ft. higher on one side than on the other. This fill had been built just before track laying, and before the heaviest rains of the season had set in. On the east and west line, the grade was largely in quite deep cutting, and the evidence showed that the roadbed was so soft and yielding that during construction it was constantly forced upward immediately adjoining the track, doubtless from the weight of the earth in the adjacent banks. The trestle, which crossed the ravine where Reservoir

Mr. Adams. No 4 was afterward built, carried the track on a 20% grade, and was built in contact with a high end bank, which, under the action of heavy rains, was amply sufficient to cause the trestle supports to be pushed seriously out of plumb.

The evidence showed that on Kingston Avenue, before referred to, the lateral movement of the track was from 16 to 20 ins. during a period of from 4 to 5 months, a rate of movement greatly in excess of anything which has at any time been observed in the big slide.

It was testified by the trackmen that the 90° curve on Kingston Avenue, in spite of its being at or near the zone of maximum movement of the large slide, had moved very little, if at all.

Again, if the same 90° curve had been moving, with the general slide, 1 or 2 ft. a year, with motion induced by the push of a saturated mass in the upper end of the slide, such an action would have resulted in the uniform crowding and buckling of the track to the east, as far as the point marked "Road to Base-Ball Ground" (Plate IV). On the contrary, the evidence showed the track to have been pulled apart and the yokes broken on this section, a phenomenon readily produced by the lengthening of the track from unequal settlement in a very soft roadbed.

Farther to the east, there was buckling of the track, according to the evidence, but it was too irregular in character, in places of occurrence, and in total amount, to harmonize in any way with the hypothesis of a general movement such as has been shown to exist since the reservoirs were excavated.

On page 177, in the extract from the report of the engineers for the Water Committee, the existence of surface slides is mentioned. The evidence in the case was full of observations of such local slides. A barn, once on the land, had been moved out of position by this cause. In one place the trees were observed to be leaning to the east, and there were various other manifestations, none of which could be reasonably attributed to the action of a slide from 60 to 90 ft. thick, moving from 1 to 2 ft. a year.

The writer has said that a study of the physical conditions, alone, also warrants the hypothesis which reconciles so effectually all the evidence of fact.

Attention is called to the exceeding slowness of the movement, as indicative of how little equilibrium was disturbed.

It must be admitted that this slide, in its movement eastward, granting that it was formerly in motion, when sufficiently in contact with the rock barrier, extending entirely across its front save for the gap closed by the lower dam, must come to a state of rest. It is not conceivable that, to reach this state of rest, a slide, consisting mainly of rock and stiff clay which without support moved only 1 ft. a year, would need to rise against the barrier to the full height

of its natural surface and thus wholly close the natural ravine there existing. On the contrary, it might reasonably be expected to rest when in but partial contact, and the extent of this contact necessary to continued repose might be, and probably was, relatively very small. When dealing with forces not far from the point of exact equilibrium, grave consequences may easily follow seemingly insignificant causes. Mr. Adams

The great weight of the moving mass has been urged in proof of the irresistible character of its movement. Mere weight means nothing in determining its energy unless its speed also is considered. If the slide were only 3 ins. thick and moving as slowly as 4½ ins. an hour, it would develop as much energy as when 75 ft. thick and moving 12 ins. a year.

With a slide claimed to be of geologic origin already in contact with a barrier which admittedly must stop its progress; with instrumental surveys having been made over its surface for six years; and exhaustive borings and examinations made by careful engineers charged to determine its stability; and with no movement discovered until excavations across almost the entire width of its front had been carried, in most places, below its plane of movement; with the discovery, at that time, of a rate of motion of something like 12 ins. a year, followed by the rapid opening of large cracks (Page 188) around the boundaries of the slide; and the tracing of these lines of fracture on both sides to points of contact with the reservoirs almost exactly coincident with the extent of their excavations, modified slightly on the south by the topography (Plate IV), the writer is impelled to the seemingly inevitable conclusion that, whatever the geological history of this land may have been, this slide was in a quiescent state prior to its being set in motion by the excavation of the reservoirs.

Vol. XXX. MAY, 1904. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

LAKE CHEESMAN DAM AND RESERVOIR.

Discussion.*

By Messrs. J. P. Frizell, Burr Bassell, F. B. Maltby, E. Sherman Gould, E. W. Harrison, Frank C. Horn and Charles S. Gowen.

Mr. Frizell. Joseph P. Frizell, M. Am. Soc. C. E. (by letter).—A faithful record of the inception, planning and execution of a great engineering work is always instructive to the profession, and, accordingly, this paper by Messrs. Harrison and Woodard on the Lake Cheesman Dam is welcomed. Moreover, the failure of an important work is often more instructive than its successful execution, and in this view, it may be said, without any disparagement to the general scope and purpose of the paper, that its most valuable feature is the account of the failure of the original rock-fill dam. This was a most unfortunate occurrence, not only as a serious pecuniary loss to the promoters of the undertaking, but as discrediting, in their minds, and, no doubt, in the mind of the general public, this mode of construction.

The future prosperity of the arid section of the United States, like that of every other section, depends largely upon agriculture, and the latter depends wholly upon irrigation. The conformation of the

* This discussion (of the paper by Charles L. Harrison, M. Am. Soc. C. E.; and Silas H. Woodard, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for March, 1904), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Communications on this subject received prior to June 25th, 1904, will be published subsequently.

Mr. Frizell.

country, abounding in deep cañons worn in hard rock, calls imperatively for high dams, and the needs of agriculture call with equal urgency for less expensive methods of building than are ordinarily adopted, or are justifiable in works of municipal water supply. These conditions are fulfilled by the rock-fill dam, and this mode of construction must not be brought into discredit by a failure, the result of an obviously avoidable accident. The record of precipitation on the drainage area appurtenant to this dam has been kept for 30 years or more. At the commencement of the work, in 1898, this record, presumably, was available for the preceding 25 years. This showed that high water occurred in the spring and early summer. In May, 1876, 22 years previously, had occurred a rainfall nearly double that of any other month in the record. Under the arrangements adopted, this might have been regarded as certain to overtop the dam. As the dam was expected to occupy two years or more in construction, the engineer accepted a chance, of at least one in ten, of its destruction while in process of building. It is true, he hoped that such another rainfall as that of May, 1876, would not occur until after the completion of the dam, but, as matters fell out, it did occur. Natural agencies worked without any regard to the engineer's wishes. Many dams of this construction might have been undertaken under chances equally or more adverse, and brought to successful completion. In this case, the fatal event happened, and the dam failed. This occurrence does not invalidate the principle of the rock-fill dam. It only shows the necessity of guarding against the danger to which the loss of this dam is due.

There are two general methods of making such a dam safe while in process of construction: (1) To construct the efflux passage with dimensions sufficient to take off the whole flow of the stream in the highest stage, under the head that can be obtained by such a low dam as can be built above the main dam; and (2) construct the rock-fill dam so that it will admit of overflow at any stage of its construction.

In this case, the first method would be inordinately expensive, and the object would be very likely to be defeated by drift-wood brought down by the first great flood.

The writer has long been of the opinion that it would conduce much to the success of the second method, as well as to the general stability and safety of the rock-fill dam, to fill the interstices of the latter with gravel or earth. The work might be executed in layers of 18 to 24 ins. in depth, and, after the completion of a layer of stone, earth might be sluiced in, or deposited, under the action of water, until the latter would stand upon the mass. The construction indicated by Fig. 12 is submitted as a method, though very possibly not the best, of constructing the dam so as to admit of overflow at any stage of its progress. This contemplates a massive crib of squared

Mr. Frizell. or flatted timber, notched, fastened together with screw- and drift-bolts, loaded with stone, and decked with thick planking. This is represented in Fig. 12 as 12 ft. deep, 20 ft. up and down stream, and extending across the cañon, which is some 30 ft. wide at the level of the deck. On the up-stream side of this crib the stone, or stone and gravel, filling is commenced. As this proceeds, the rods, *r*, *r*, *r*, are inserted, anchored to the wooden blocks, *a*, *a*, *a*, at the bottom, and adjusted to receive the sleepers, *b*, *b*, *b*, which are embedded in the rock filling, and solidly confined by nuts and washers. To these sleepers, a layer of 3-in. plank is spiked, not necessarily in contact, but leaving intervals of 2, 3 or 4 ins. In carrying forward this work, the aim should be to keep the uppermost sleeper some 6 ft. higher than the general level of the dam; at least, this should be the condition when the water comes to the existing level of the dam. It is obvious that such an event could not occur without warning and time for preparation.

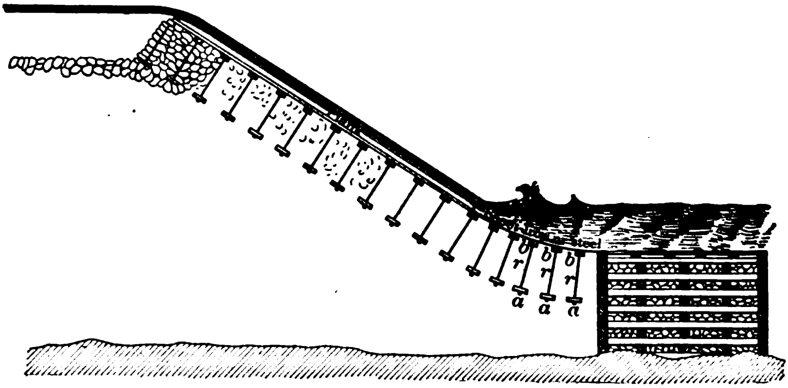


FIG. 12.

Suppose, in the case under consideration, that the work is up to where the valley is 150 ft. wide. Assume that the maximum flood seeking egress is 3 000 cu. ft. per second; 20 cu. ft. per second per foot of length of the overflow, involving a depth on the crest of somewhat more than 3 ft. The water is then some 9 ft. in depth on the unprotected filling, and moves across it with the very moderate velocity of a little more than 2 ft. per second, a velocity incapable of dislodging the smallest stone. The sketch, Fig. 12, it will be noticed, contemplates the laying up of the stones under the uppermost sleeper in an orderly manner in preparation for an overflow. By turning up the nuts at the heads of the rods, a pressure can be brought upon these stones, rendering them immovable.

It will be obvious that the danger of overflow diminishes rapidly as the dam rises, but is much greater in the early part of the work

than later on, for these reasons: (1) Because, in the latter case, the flood is more largely expended in filling the reservoir; (2) because the discharge through the efflux passage is greater, owing to the increased head. Mr. Frizell.

This mode of protection, applied to the case under consideration, would have involved something like 1 000 000 ft. of lumber, of an inferior grade, and not more than 400 000 lbs. of iron.

The paper is somewhat incomplete as regards the efflux arrangements. Under so great a head, and with so large a volume of water, a more detailed description of this feature is desirable. The inquiring reader might at least desire to understand the necessity for providing three efflux passages at different depths. Does this disposition rest upon any substantial reason, or upon a mere tradition of the engineering profession?

Neither the statical principles of the stability of walls nor of arches can be given full effect in the discussion of this structure, though the latter apply much more fully than the former. It is customary to say, in objection to the arched form of dam, that a ring of the arch cannot transmit to the abutment the pressure sustained by it without breaking its connection with the ring below, and that the dam, as a whole, cannot transmit its pressure without breaking its connection with the bottom. This proposition should be more carefully considered.

Regard the dam, with Mr. Woodard, as made up of a series of rings. Consider the action on the upper ring, assumed to be level with the water at the top. It is only in virtue of some slight deformation of the ring that its pressure can be transmitted to the abutments, and this deformation, it will be said, is resisted by the ring below, through friction and the tensile or shearing strength of the mortar. Remember, however, that no part of the bottom or sides of the cañon is entirely unsusceptible of deformation. Now consider the second ring. This sustains a greater pressure than the one above it, and its tendency to deformation operates to transmit the pressure on the upper ring more fully to its abutment. The pressure on the third ring has the same tendency, and so downward. The deformation of each ring is aided by its connection with the ring above, and resisted by its connection with the ring below, and it takes deformation approximately, but not fully, equal to that due to the water pressure acting directly on it. The direct pressure on the ring, not transmitted to the abutment, is transmitted to the bottom and sides of the cañon, through friction and the tensile and shearing strength of the mortar. It results in a deformation of the material different from any that occurs in the straight dam or the vertical arch: a deformation, namely, in which the upper face of any block tends to move with reference to the lower face.

Mr. Frizell. The computation of the stability of a straight dam of the given cross-section, and in the given situation, without considering any forces other than the weight of masonry and pressure of water, is merely a conventional and academic exercise. Not that such a computation would lead to an unsafe section, but that it ignores forces larger than those of which it takes account. Apply such a computation, for instance, to the part, about 30 ft. wide, that rests on the bottom of the cañon and sustains the entire head of water. This part cannot be overturned without breaking its connection with the remainder of the dam. There is found a pressure of some 45 000 000 lbs. tending to overturn this portion. If the shearing strength of the masonry is estimated at 100 lbs. per square inch (say, for convenience of computation, 1 500 lbs. per square foot), the average thickness of the masonry being something like 100 ft., it is found that there is a force of some 220 × 110 × 15 000 × 2 = 726 000 000 lbs. tending to resist overturning. Or, if the stability of the entire dam be considered as a body, it cannot be overturned without breaking its connection with the cañon along the entire perimeter of the latter. In fact, it cannot then be overturned without breaking and crumbling into many pieces. In this case, the force tending to push the dam down stream is something like 400 000 000 lbs. The shearing strength resisting this movement is something like 1 260 000 000 lbs. Certainly, if computation shows a margin of safety in disregard of these enormous forces, the dam ought to be safe.

To give an arched form to a dam involves much additional expense and labor, and it would seem that this expense and labor ought to be attended with a diminution of material. Of course, the engineer's aim is to secure safety beyond the possibility of a doubt, but to go beyond this point involves a waste of material. Where dimensions are adopted which make the structure abundantly safe, regarded as a straight dam, it seems to be unnecessary to give it a curved form.

The furnishing of the cement by the owners, instead of requiring the contractor to furnish it, was a highly commendable feature of this work. No stipulations of a contract are more easy to evade and more difficult to enforce than those which relate to the mixing and the use of mortar. Where the contractor furnishes the cement he is under constant inducement to withhold it from the work. Though he may, ostentatiously and loudly, enjoin upon his men full compliance with the terms of the contract, they readily discern his real wishes, and comply with them. There is no security for the proper use of mortar, unless the use is made to coincide with the contractor's interest.

Mr. Bassell. Burr Bassell, M. Am. Soc. C. E. (by letter).—The writer has read this paper with pleasure, and, while he does not wish to make a technical discussion of the paper, his interest in the construction of dams in general, and his familiarity with different types and profiles of dams, leads to a few remarks.

In Fig. 11, Mr. Woodard has shown comparative sections of eight dams, including the Lake Cheesman Dam. The writer regrets that the Lake Hemet Dam, California, was not selected instead of the smaller Sweetwater Dam, for two reasons: In the first place, the profile across the cañon at the Hemet Dam site does not differ materially from that of the Cheesman Dam site, after eliminating the lower 30 ft. of the latter, or, in other words, they are practically the same between Elevations + 20 and + 170. Again, the Hemet Dam is about the same height as the Ban Dam, in France, designed to be 165.5 ft. above the lowest foundation, or 152.5 ft. above the creek bed. Mr. Bassell.

The base elevation of the latter corresponds to Elevation + 70 of the Cheesman Dam, at which point they are within 0.51 ft. of the same thickness. The Hemet Dam has a very simple profile or section, having a straight batter of 1 in 10 on the up-stream face and 1 in 2, or 5 in 10, on the down-stream face. Plotting this profile on Fig. 11, and producing the face line downward for deeper foundations, or to correspond to a dam of the same height as the Cheesman Dam, the following points may be noted by way of comparison: The Hemet and Cheesman Dams are of practically the same thickness at Elevations + 70 and + 207 (Cheesman) or Elevations 0 and + 137 (Hemet), being 100 ft. and 18 ft., respectively.

The Cheesman Dam is 176 ft. thick at its foundation base, while the Hemet Dam section would give 148 ft., or 28 ft. less. This means that in the lower 80 ft. of the Cheesman Dam there is a sectional area of 1 120 sq. ft. in excess of the Hemet section. On the other hand, in the upper 150 ft. of the Cheesman Dam, corresponding to the Hemet Dam, the latter has an excess of almost identically the same sectional area. For straight gravity dams, this simple section is certainly safe, and for dams curved in plan it is not much in excess of an ideal section.

In the discussion of curved dams, where arch action may be brought into effect, the bold structure of the Bear Valley Dam, California, is always cited. As a matter of record, the writer will here state that he pointed out the secret of its stability, ten years ago, in the columns of *Engineering News*. This dam was built under hydrostatic pressure, insuring a perfect arch. This method of construction might be used to advantage again, but, certainly, never so bold a section.

The writer appreciates the importance of careful computations to obtain both safe and economical sections for a dam, especially if the dam is high or has a long crest. He also realizes fully the importance of sufficient base width and bed-rock anchorage; however, he is inclined to favor simplicity in design, and would not build too close to theoretical lines in the upper portion of a dam, for fear of seismic disturbances and for other reasons. Furthermore, there seems to be less reason for extending the thickness of that portion of the dam

Mr. Bassell. which is below the surface of the ground beyond the limits of the simple section suggested than for decreasing it above.

What the writer wishes to point out, and have fixed in the minds of the younger members, is the simple section here presented which agrees so well with approved profiles for masonry dams, and is represented in actual practice by the Lake Hemet Dam, California. He would recommend, for the lower half of a masonry dam of any height, a thickness of six-tenths of the depth from the top, plus the crown width.

Mr. Maltby. F. B. MALTBY, M. AM. SOC. C. E. (by letter).—The writer has been greatly interested in the description of this work, as he is quite intimately acquainted with the locality. In May and June, 1897, he was employed, under H. M. Chittenden, M. Am. Soc. C. E., Captain, Corps of Engineers, U. S. Army, in making some surveys and examinations of reservoir sites in Colorado and Wyoming for the War Department. He also assisted Captain Chittenden in the study of the development of the various projects and in making plans for the proposed dams. Among others, the reservoir site now known as the Cheesman Reservoir was carefully surveyed, and plans for the dam prepared. The report of these surveys, with maps and plans of the proposed structure, was published as House Document No. 141, 55th Congress, 2d Session; and also in the Annual Report of the Chief of Engineers, U. S. Army, for 1898, p. 2815 *et seq.*

The contour map, Fig. 2, is so similar to the one printed in the foregoing report, almost every indention or projecting point in the contours being identical in each, that the writer wonders if one is not a reduction from the other.

A masonry dam was proposed at identically the same point and of the same height. The curve of capacity, given in the foregoing report, is identical with that given in Fig. 3. In making studies for the proposed dam at this site, the writer made, for Captain Chittenden, some ninety-five comparative cross-sections of the high dams of the world.

A rock-fill dam with a steel core, similar to the Otay Dam, in California, was considered, but it was thought that the vast interests of both life and property which would be endangered by the failure of a dam of such magnitude as proposed at this point prohibited the building of any structure which contained an element of danger. For this reason, a masonry dam was proposed. It was to be 200 ft. in height above original low water, or with a total height of about 220 ft. It was proposed to build it on a curve, in plan, having a radius of 300 ft. It is noted that the dam, as described and built, has a curve with a radius of about 400 ft. It was also proposed to make the spillway over a natural saddle of rock, as described. The section proposed was very similar to the one built, having a width of 20 ft.

on top and 175 ft. on the bottom, as compared with 18 and 176 ft. as built. Mr. Maltby.

It is a source of gratification to the writer to know that plans for this structure, as given in the above-mentioned report, agree so closely with the plans of the structure as finally designed and built by such eminent men in their profession as were employed as Chief and Consulting Engineers.

Mr. Gould. E. Sherman Gould, M. Am. Soc. C. E.—This paper, taken in connection with recently published descriptions of similar structures in Australia and California, is of great value at the present time. It seems likely that the high masonry dam of the future will be of the arch type, receiving, sustaining, and transmitting to abutments the stresses acting upon it, rather than opposing them by its mere dead weight, or the moment of its dead weight. In this, the art and science of dam building is but following the universal drift of all branches of construction, in reducing the amount of material used by a more intelligent distribution of it. This is accomplished, generally, by analyzing the stresses acting upon the structure, and framing it of pieces the axes of which coincide with the lines of stress. Also, in the choice of the material used; the growing substitution of light forms of reinforced concrete for massive rubble being a step in this direction.

The structure described in the paper is peculiar in that the arch form seems to have been adopted more with a view to fit the work to the ground than for any other motive. Seeing that the dam, if started straight from one end, must be deflected in order to reach proper ground at the other, it was preferred to meet this necessity by a curved line rather than a broken one, in order to secure whatever additional strength the arch form might give it. If it had not been for the peculiar topography of the site, it appears that a straight dam, with what for convenience is termed a "gravity section," would have been adopted, and, indeed, such a section was adopted and counted on to sustain the pressure, the arch being considered only as incidental and merely affording whatever additional strength might reside in it.

Now, the speaker considers that this combination is radically faulty; that the two systems, arch and gravity, do not aid but rather conflict with each other, and that a section which is right for one is wrong for the other. He does not wish to be understood as saying that if an arch dam, with its lighter section, were sprung across a valley, its stability would not be increased by adding to its base a further mass, such as would be required to give it the form of a gravity section; what he does wish to say is, that if such additional material were put into the work, it could be more advantageously placed elsewhere. Furthermore, he would wish it to be understood

Mr. Gould. that in all that he has said, and is about to say, he refers to those cases where the curve is so pronounced as to form a veritable arch, and not a mere camber.

When a dam with a gravity section is built on a curve, its strength to resist crushing or overturning as a gravity dam is impaired, although the deficit is more than compensated by the setting up of the arch action. Therefore, it cannot be considered as possessing all its gravity strength with all its arch strength super-added. The total hydrostatic pressure against it is increased in the ratio that the arc of the curve is greater than its chord, while the resisting area at the toe is reduced, measurably, in the same proportion.

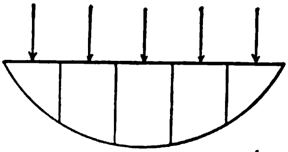


FIG. 13.

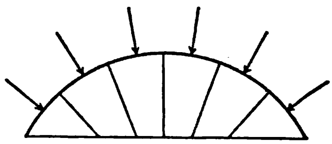


FIG. 14.

These conditions may be seen by reference to Figs. 13 and 14, which show two ideal though quite possible plans, Fig. 13 being that of a straight dam and Fig. 14 that of a curved one, both having the same span. The total pressure upon the curved back is, in this case, six-fifths of that on the straight back. If Fig. 14 is developed, it gives Fig. 15, which shows that the resisting area of the dam is diminished by the gores left vacant by the development.

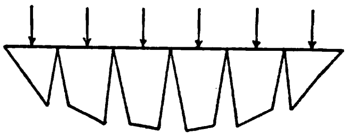


FIG. 15.

But when the arch form is frankly invoked, as in the present case, why should the gravity feature be retained in the problem? The forces with which the dam contends are: sliding forward on its base; overturning around the outer edge; and, in the case of very high dams, the crushing of the material when the dam is sustaining a full head of water. If the dam is straight, and is cut into imaginary slices, say, 1 ft. thick, all of these phenomena may be produced upon a given slice without disturbing the adjacent ones. In a curved dam this could not take place without setting up violent lateral reactions because the imaginary slices, having their axes in the same lines, as the pressures are no longer parallelogramatic, but wedge-shaped, and cannot be thrust forward or made to rotate without pushing aside or crushing the adjacent ones. It seems to the speaker, therefore, that a gravity section implies a faulty design when applied to an arched dam, because it provides for a class of stresses to which the structure cannot be subjected.

In the speaker's opinion, the calculation for this dam should have Mr. Gould. been made wholly upon the arch proposition. Mr. Woodard states that this calculation was made, but does not give the method used nor the results, which fact must be taken as a proof that he considered them satisfactory.

The speaker is not aware what method of calculation has generally been used for arched dams, considered simply as such. In some respects it would seem that the calculation must be simpler than for an ordinary arch sustaining a vertically acting load. The weight of the dam itself is not borne by the arch, and the pressure that it does sustain is uniform per unit length of surface, and is directed at all points toward the center of the curve. The line of pressure, therefore, as Mr. Woodard states, must correspond with the curve. What is wanted is the horizontal compressive stress per unit of section. Navier's formula appears to be peculiarly adapted to this calculation, because it is based precisely upon the hypothesis of fluid pressure, and is only applied to other cases by a more or less permissible extension. Navier's formula, as is well known, is as follows:

$$Q = P\,R' \qquad \text{(1)}$$

In this formula, referring to Fig. 16, Q = the compressive stress upon any horizontal strip, of length, x, and unit width, the unit in this case being 1 ft., situated at the depth, h, below the surface of the water which is assumed to be level with the top of the dam. P = the horizontal pressure at the depth, h, upon the unit surface (1 sq. ft.), and R' = the radius of the curve of the intrados of the arch. In this case $R' = R - x$; R being the radius of the crest of the dam. R, of course, is constant, while R' varies with the value of x.

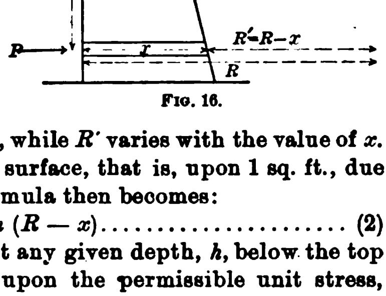


Fig. 16.

The pressure upon the unit of surface, that is, upon 1 sq. ft., due to the head, h, is 62.50 h. The formula then becomes:

$$Q = 62.50\,h\,(R - x) \qquad \text{(2)}$$

To find the proper value for x at any given depth, h, below the top of the dam, a value for Q, based upon the permissible unit stress, must be assumed. The value of Q would then be this stress multiplied by x, since x, being of unit width, is the section which must resist the pressure. Designating this limiting stress by L, we have:

$$L\,x = 62.50\,h\,(R - x);$$

whence

$$x = \frac{62.50\,h\,R}{L + 62.50\,h} \qquad \text{(3)}$$

Mr. Gould. This is the general expression for the value of x at any given depth, h, when the radius, R, and the limiting stress, L, are given.

It is evident that a high value may be assigned to L, because the pressure, particularly near the base of the dam, is exercised, not upon imaginary isolated strips, as has of necessity been assumed in the formula, but upon strips embedded in a mass of masonry. $L = 30\,000$ lbs. would be a conservative value, under the circumstances. In the Lake Cheesman Dam, $R = 400$ ft. Inserting these values in Equation 3 and reducing, gives:

$$x = \frac{400\,h}{480 + h} \qquad (4)$$

This is the working formula adapted to the present particular case, and by its aid a series of values of x can be calculated, as in Table No. 4.

TABLE No. 4.

Elevation.	h	x	Actual length.
0	220	125.70	166.58
50	170	104.60	119.36
100	120	80.00	72.66
150	70	51.00	37.00
200	20	16.00	18.00

The profile thus determined is shown in Fig. 17, upon which the actual profile of the Lake Cheesman Dam is also shown, approximately, in dotted lines.

Now, whether or not the value of L is rightly chosen, whether the resulting profile, as shown in Fig. 17, is too bold or not bold enough, the fact which the speaker is seeking to establish is that, at least in his opinion, the proper profile for an arched dam is of the general shape shown in Fig. 17, rather than the one actually used, and it is upon this point, for his own enlightenment, that he would be glad to know the opinions of others.

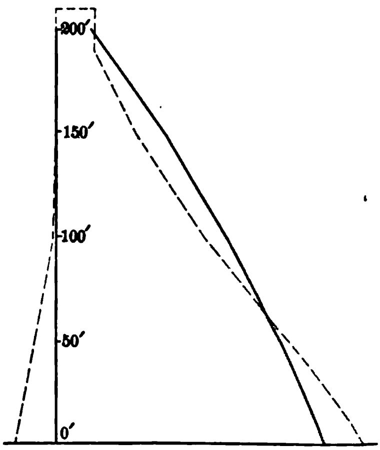


Fig. 17.

Also, he would suggest the following questions as needing further elucidation:

Can the thrust of the water in the arch dam be considered as being transferred totally to the sides of the valley, and, if so, is it neces-

-sary to consider the vertical pressure upon the base of the dam as anything more than that due to the weight of the dam itself, when the reservoir is empty? The extreme thinness of some existing, high, arched dams would seem to indicate that it is not. Mr. Gould.

It would require much more time than is now at command to follow and verify the skilful, but intricate calculations and assumptions developed by Mr. Woodard. The results shown in Fig. 10 are surprising in that they exhibit so slight a difference between the lines of pressure for a full reservoir, with and without the aid of the arch. They seem to indicate that the very pronounced arch form added practically nothing to the strength of the dam.

Against the heavy profile of the Lake Cheesman Dam there must be set off the many very light arch dams already built and standing intact. Apparently, there is discord between theory and practice in regard to structures of this class. If calculation shows that these dams are too frail to sustain the forces acting upon them and they yet persist in standing up, then it would certainly seem that there is something wrong with the theory upon which the calculation is based.

One fact it is well to bear in mind, as explaining the frequent disagreement between fact and theory, in the case of retaining walls in general, and of dams in particular, and that is the enormous difference between the assumed data and the actual conditions, resulting in a great but neglected factor of safety. When the resistance of a gravity dam is calculated, a slice 1 ft. thick is taken at the point where the dam is the highest, and is considered as standing alone, without any lateral support, and depending for its stability wholly upon the moment of its mass.

Then (neglecting besides the adhesion of the mortar), this slice is considered as representing the entire dam. If the dam were of equal height throughout and of indefinite length, and if it fell, if it did fall, in one body, as a door turns upon its hinges, this would be a correct assumption. But no dam was ever overturned in this way, nor could it be. There is no continuous edge about which it could rotate bodily. The valley across which it is thrown is more or less V-shaped, and the whole structure could not be made to rotate about the comparatively small fulcrum which the topography of the site afforded. Every foot of the dam would have a different point about which it would tend to rotate, and no single slice or section could rotate without tearing asunder its connection with the adjacent sections. An enormous proportion of the overturning force would be absorbed in the shearing effort necessary to accomplish this, and of this no account is taken, the result of our calculations, therefore, being tremendously on the safe side. No doubt many anomalous conditions may be thus accounted for.

Mr. Gould. Something is said in the paper about strains due to changes of temperature. It appears to the speaker that, considering the great thickness of such structures, entirely too much importance is attached to this feature. The effects of changes of temperature cannot penetrate beyond a very few feet, leaving the temperature of the mass practically uniform at all seasons of the year.

Mr. Harrison. E. W. Harrison, M. Am. Soc. C. E.—The most salient feature which strikes the speaker, in reading this most admirable description of a beautiful piece of engineering work, is the illustration it gives of, probably, the highest type of engineering skill and ability—the art of seizing upon natural features and conditions, and utilizing them to the best and most economic advantage for the purpose sought to be obtained.

Secondly; how often skilful engineers fail to grasp these opportunities, and, in the very conception of a plan, go wrong and produce results far below the possibilities lying open to their brains and hands.

To use an illustration familiar to all engineers who have studied, from an observation car, or as delineated upon a topographical map, a railroad located in a difficult country: how many millions of dollars could have been saved in construction, maintenance and operation, if the locating engineer had only possessed that useful sense of imagination which sees, ahead of the transit, the completed grade winding around the mountain sides and crossing the summits, and makes the configuration of the earth surface assist him in obtaining the location which cannot be bettered.

In the present case there is the condition of very small rainfall, and, what there is, occurring during a short fraction of the year. This entails large storage, and, if possible to obtain, deep reservoirs with little surface for evaporation. To avoid waste, the dam and reservoir should be as tight as skill can make them, as every gallon saved from leakage and evaporation, prolongs the period in which the available supply will suffice for the growing demand, and increases the growth of the sinking fund which, some day, will be required to extend the supply.

The contour map shows the selected reservoir site to be perfect to fulfill these conditions, and the location chosen for the dam is ideal.

The speaker, in the past ten years, has had occasion to make many studies of the topography in different parts of the country for the purpose of selecting advantageous and economical sites for storage reservoirs and dams, and cannot remember any example in which the combination of all natural features, except rainfall, needed for a water supply, and to secure large storage and a deep reservoir advantageously, were so combined as in the case under discussion.

Yet, after selecting a narrow gorge with solid granite sides and floor, where Nature had provided an ample and excellently located

spillway, with quarries of the very best material near by—in fact, a theoretically perfect location for a masonry dam of the most economical proportions—all these advantages were nearly thrown away, and work was actually commenced on a rock-filled dam, faced with a sheet of concrete and steel plates. Mr. Harrison.

Fortunately, for the enterprise, the flood of May, 1900, destroyed the work on this structure, and, presumably from the paper, resulted in bringing into the project new engineering talent, which saw the opportunity presented, and was wise enough to grasp it.

The proper character of the work being adopted, the actual carrying out of the plans presents no remarkable features, and is a matter of detail.

The section for the dam is bold, and, considered as a gravity dam, is only just on the line outside of which the best precedents forbid an engineer to go, but the designer seems to be justified in his confidence, not only by the fact of the unexcelled character of the foundation and abutment rock, but also by having the security of the arch form as a final resort.

Compared with the section adopted for the Boonton Dam, with which the speaker is connected, the section of the highest 110 ft., of the Boonton Dam has an area of 3 836 sq. ft., as against 3 254 sq. ft. in the upper 110 ft. of the Lake Cheesman Dam.

Under any but exceptional conditions of situation and other advantages, as found in this case, the speaker would feel easier with the larger section, though the Boonton Dam, for many reasons—among others the resistance to ice pressure—was treated in a very conservative manner.

From the information given in the paper, the speaker is of the opinion that a saving in cost could have been secured by using the Cyclopean, rubble-concrete masonry which was adopted at Boonton.

The cement estimated as needed, 80 000 bbls. for 103 000 cu. yds. of masonry, or more than 0.77 bbl. per cubic yard, exceeds the proportions actually used at Boonton, which was 0.68 bbl. per cubic yard for more than 200 000 cu. yds. of masonry of all classes..

The weight of a cubic foot of masonry in the Lake Cheesman Dam, is given at 158 lbs., which in itself is excellent, but the average weight in the Boonton Dam—syenitic granite, in concrete—is 166 lbs per cubic foot.

Frank C. Horn, M. Am. Soc. C. E. (by letter).—The sand used in the construction of the dam was washed after passing through a screen made of parallel bars spaced $\frac{3}{8}$ in. apart. The grains ranged in size from the largest that would pass through the screen to fine sand. About 34% would be retained on a No. 6 sieve and 66% would pass through it. A number of tests were made to determine the voids, which were found to be about 31.5% of the volume. Mr. Horn.

Mr. Horn. The mortar used in pointing was mixed in the proportions of 2 parts of screened sand to 1 part of cement. The mixing was done in batches of 5 cu. ft., by a batch mixer. The operation of mixing the mortar was watched by an attendant, and a uniform product was always secured. The mortar boxes were each of 10 cu. ft. capacity, and, after being filled, the mortar was distributed as the necessity of the work demanded, and was not allowed to accumulate on the wall. The contents of each mortar box were used within about 30 minutes after having been placed for the masons. Tests were made, from time to time, to determine the tensile strength of the mortar. The results are shown in Table No. 5.

TABLE No. 5.—TESTS OF STRENGTH OF MORTAR, LAKE CHEESMAN DAM.

2 to 1 mortar.			2½ to 1 mortar.		
Age of briquette.	Number broken.	Average tensile strength.	Age of briquette.	Number broken.	Average tensile strength.
7 days	75	378 lbs.	7 days	128	320 lbs.
28 "	110	487 "	28 "	185	462 "
6 months.	45	562 "	6 months	105	527 "
....	....	....	1 year	64	561 "

The mortar for making tests was taken from the mortar boxes on the wall. The briquette moulds were filled in the usual manner and placed in the shade under a damp cloth for 24 hours after which they were removed from the moulds and placed in water, where they remained until the date of breaking. They were broken immediately after removal from the water. They were subjected, as nearly as possible, to the same treatment as the mortar used in the masonry.

The stones in the up-stream face of the dam average 30 cu. ft. in volume, and those in the down-stream face about 27 cu. ft. Those used as backing range from 6 to 90 cu. ft. in volume. Each stone was set in a full bed of soft mortar, and worked down to an even and firm bearing, until the mortar on all sides was forced out by the weight of the stone and the action due to working it with the bar. All remaining spaces were filled with soft mortar, into which smaller stones were carefully and firmly placed, care being taken to bed in mortar each stone, large and small, and not allow contact one with another. The bonding of the stones in the wall was given particular attention. No leveling of the wall at any point was permitted, except for setting the up-stream face stones, but a thorough bonding, horizontally and vertically, was secured. Fig. 1, Plate XVIII, and Fig. 1, Plate XX, well illustrate the character of the work.

LAKE CHEESMAN DAM.

The percentages of stone and mortar entering into the completed masonry are about 72 and 28, respectively. Mr. Horn.

The masonry, up to this time, is water-tight. Water has stood at Elevation 97.0 for a year, and no leaks, or even sweating, are discernible on the down-stream face of the dam.

Plate XXX is a view of the top of the dam, taken after the completion of the parapet walls, but before finishing the concrete roadway.

CHARLES S. GOWEN, M. AM. SOC. C. E. (by letter).—This is a very interesting and valuable paper, particularly when it is considered that this dam is designed and has been built to withstand a clear static head of more than 200 ft., and that, from the account of the authors, there was no sign of percolation or sweating under its first test of more than 100 ft. of static head. It seems to the writer that such a result is remarkable, and it is evident that, in the material, methods of construction, and workmanship, the very best of judgment and skill were used. It would be of great interest to know the result due to the increased head which, no doubt, has been used against the dam during the past winter. Mr. Gowen.

It is evident that the section of the dam described in the paper, namely, that below Elevation 100, was not affected by temperature, and that there were no shrinkage or temperature cracks of account, in the masonry, and, if the writer is not misinformed, he understands that since the completion of the structure to its elevation of 217 ft. no shrinkage or temperature cracks have developed in the masonry, beyond two very slight ones which show at either end of the structure, leaving a clear stretch or length of 700 ft. of the thinnest section of the dam in which no cracks are found.

To judge from the description and illustrations, it would seem that the masonry of the dam was carried up uniformly, practically without steps or racks, excepting such as are described as having been used to break bond in the masonry horizontally. In view of the presence of shrinkage or temperature cracks in the narrow sections of high masonry structures, ordinarily, and of the annoyance occasioned by them, it may be well to consider the reasons why their absence has been so marked in this structure.

At the New Croton Dam, the masonry of which, it may be said, can be divided into three parts, the first comprising the main dam, proper, which is built on a straight line; the second comprising the curved portion of the overfall, which curve is nearly a quadrant, and the third comprising the remaining portion of the overfall, which is built in tangents with two or three angles; the cracks which have developed are particularly noticeable in certain portions of the main dam and the straight portion of the overfall. These cracks, of greater or less size and extent, owing to certain conditions, are confined to the upper or

Mr. Gowen. thinner portions of the sections in question, but, in the curved portion of the overfall, which has been subjected to the same conditions as have obtained in the straight portions of the dam, no cracks have been found.

While temperature or shrinkage cracks are likely to be concentrated at particular points in case the masonry is not carried up at uniform elevations, it is unquestionable that, with uniform areas of section, they would occur at intervals more or less regularly in any thin masonry structure compactly built on a straight line. This, the writer thinks, is shown clearly enough in the work at the New Croton Dam, at certain points where the methods adopted resulted in a comparative uniformity of lines of elevation and sections of masonry as they were built. At other points it is evident, from the size and depths of the cracks, that the variations of sections, and longitudinal racking had a great deal to do with the concentration of the cracks. In the masonry of the Lake Cheesman Dam, however, it seems to be clear that its curved plan and the uniformity of section which was preserved throughout its construction had evidently to do with the remarkable absence of temperature cracks which has been noted, and the writer thinks it may be said that these results constitute a pretty good argument in favor of building high masonry dams on curves, if circumstances are such as to allow it without an undue increase in expense.

Another point of interest in connection with this dam is the provision made for waste by means of the overfall, the length of which is stated to be 300 ft. Apparently, this overflow will pass about 10 000 cu. ft. per second, a flow approximately five times as great as the largest observed flow of the river in thirty-two years. As a matter of comparison, the overflow of the New Croton Dam is 1 000 ft. long, and the probable maximum depth of flow over it may be assumed at 6 ft. Such a depth would give a flow of approximately 45 000 cu. ft. per second, or about three times the observed maximum flow of the Croton River for the past sixty years. If it be assumed that the possible run-off from the Croton Basin above the New Croton Dam is equivalent to a rainfall of 6 ins. in 24 hours, or at the rate of ¼ in. per hour over the whole water-shed of 360 sq. miles, the run-off would be 55 000 cu. ft. per second, which is equivalent to a depth of about 7 ft. on the overflow.

While an overflow capacity of five times the maximum flow of the river, as observed through a somewhat extended time, may be considered a conservative provision, and while, of course, there can be no comparison properly between the possible run-offs from the Lake Cheesman water-shed and the Croton water-shed, owing to the great difference in areas and rainfalls, the comparison between the provision made in either case, based upon observed maximum flows, is interest-

ing, and the writer, therefore, calls attention to it. As stated, no comparison can be made as regards possible maximum flow, but, if it be assumed that this rate of run-off is in inverse proportion to the water-shed areas, then, on the basis of the 6 ins. in 24 hours, assumed in case of the Croton, 6 divided by 5 equals 1.2 ins. From the Lake Cheesman water-shed, the run-off, based upon these figures, would be approximately 63 000 cu. ft. per second. Mr. Gowen.

Continuing the reductions further, and in proportion to the respective mean yearly rainfalls of the two basins, 48 ins. for the Croton and 14 ins. for the Platte, then, approximately, the possible maximum is 18 000 cu. ft. per second, a result which, if considered seriously, is seemingly out of proportion to the length of overflow provided.

The records of the United States Geological Survey show flood flows of certain streams in Kansas and Colorado which, apparently, approximate closely, if they do not pass, the limit of 10 000 cu. ft. per second for the 1 800 sq. miles of the Lake Cheesman water-shed. Accepting such records as reasonably reliable, it would seem that greater flows might be expected than this overflow is calculated to provide for.

An acquaintance with the characteristics of this particular watershed is certainly essential in order to justify any criticism of the feature in question, and the writer, therefore, is not disposed to undertake it; but if the information on which the dimensions of the overflow were based can be supplied, it would prove a very acceptable and valuable addition to this paper.

The plans made for regulating the outflow from the reservoir were formed, it is evident, in connection with the rock-fill dam design and were partly completed before the new design for a masonry dam had been adopted. The tunnels, it is assumed, are unlined, excepting at the points where the valves are installed, and the question arises as to the need, in time, of additional tunnel lining, and it is certainly a matter of great interest to know how the valves in question are working under the pressures that must obtain. The addition of the Tainter guard-valve was certainly very essential, and the precautions taken to provide the manway tunnels to give access to the working parts of the discharge valves at all times were certainly prudent, to say the least. It is improbable, of course, that all three, or that two out of three, valves will be out of order at any one time, and the contingency is remote that the control of the flow might be lost in consequence, or that in such case the depths of the water above the dam would be beyond the limit of a diver's work, but it would seem to the writer that some provision should have been made, if such has not been done, by which the upper entrances at the 60-ft. and 110-ft. levels can be closed upon emergency and clear access to the valves thus afforded.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

BENJAMIN BURGH SMITH,* M. Am. Soc. C. E.

DIED FEBRUARY 8TH, 1904.

Benjamin Burgh Smith was the eldest son of Dr. Benjamin Burgh Smith and Catherine Smith Farr. He was born at Georgetown, South Carolina, on May 15th, 1835. His education was completed at the South Carolina Military Academy, from which school he was graduated in 1855.

Choosing Civil Engineering as a profession, he secured an appointment on the Engineer Corps engaged in the surveys of the Charleston and Savannah Railroad. His connection with this organization lasted upwards of two years, when young Smith decided to study medicine, influenced no doubt by the advice and example of his father. He attended the medical lectures in the South Carolina Medical College at Charleston, South Carolina, and was graduated in 1859 or 1860. During the intervals between the sessions of the medical College, he was employed on the construction of the Charleston and Savannah Railroad, in charge of track laying.

The opening scenes of the Civil War soon attracted Dr. Smith, and he promptly abandoned his profession and entered the service of the Confederate States. Into this service he threw himself with all the ardor of an earnest nature, and was distinguished for his gallantry, good judgment and military skill. He attained the rank of Colonel and was included in the terms of the surrender of General Jos. E. Johnston to General Sherman.

Subsequently to the Civil War he resumed the practice of his profession at Adams Run, South Carolina. Having been left without means, he was not able at that time to purchase a horse, but illustrated his high character by walking long distances to practice among the poor.

The poverty of the section in which he lived forced him, after a time, to abandon the practice of medicine and to resume the practice of engineering. After being engaged in surveys of railroad lines of less importance, he joined the Corps of Engineers making the surveys and location of the Port Royal Railroad, and continued in this service until the completion of the road to Augusta, Georgia.

* Prepared by the Rev. Ellison Capers, Col. C. S. Gadsden and James P. Allen, M. Am. Soc. C. E.

He then entered the service of the United States, and soon thereafter, obtaining the position of Assistant Engineer in the United States Light-House Establishment, he continued in that position until his death on February 8th, 1904.

To the duties of this position, which was practically his life work, he devoted himself with all his natural zeal and energy. His good judgment and intelligence gave great weight to his opinions in all matters relating to the engineering work of the Sixth Light-House District.

Col. Smith was a man of sterling qualities and strong character. He never married, but his beautiful home life among his relatives, to whom he was devotedly attached, will be held by them in lasting remembrance.

Col. Smith was elected a Member of the American Society of Civil Engineers on November 7th, 1888.